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RESULTS OF THE DIARY SCHEME

by

K. RADWAY ALLEN

and

B. T. CUNNINGHAM
Fisheries Branch, Marine Department

Wellington, New Zealand
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PREFACE

WHEN the fresh-water fisheries work of the Marine Department was reorganised in 1946–47, the existing knowledge of New Zealand's fresh-water fisheries was studied to determine which were the most urgent problems calling for study by the expanded research staff. It was apparent that throughout the country there was a dearth of information as to the state of trout stocks, the quantities of fish being taken by anglers, and the size of the fishing effort. All this information was necessary if the management of the country's fisheries was to be placed on a sound basis, and its collection became one of the first objectives of the Department's research organisation. A much wider coverage of the country was needed than could be achieved by the direct efforts of research staff, and it was obviously necessary to call on the anglers themselves for assistance. In this way the General Diary Scheme, which forms the subject of this report, came into being.

The diaries were collected from anglers by the acclimatisation societies and forwarded to the Fisheries Laboratory of the Marine Department for analysis. Here the senior author has been responsible for the original planning, some of the final special analyses, and the writing of this report, while the junior author undertook the organisation of the diary material as it came to hand and supervised its transcription and the preparation of the basic tabulations. Our thanks are due to the many members of the laboratory staff, permanent and temporary, who have, at various times, helped in the laborious task of copying and tabulating the data from the original diaries; also to the Secretary of the Treasury and to Mr I. D. Dick and Dr R. M. Williams, at different times Director of the Applied Mathematics Laboratory, Department of Scientific and Industrial Research, who all made staff and equipment available to undertake the mechanical analysis of the data in the last two years of the scheme; to Dr M. A. F. Barnett, Director of the Meteorological Service, who provided special data on weather conditions; to the Government Statistician, who made available for our analysis unpublished census data; to Mr P. Dickinson, Mr R. M. Cassie, and Dr P. Whittle, who read all or parts of this paper in manuscript and gave us much helpful criticism.

Our gratitude is especially due to the councils and officers of those acclimatisation societies which took part in the scheme; their efforts in distributing and collecting diary forms and in persuading anglers to keep the records were vital to its success.

Finally, and most important of all, we must thank more than 800 New Zealand anglers who went to the trouble of keeping detailed diaries for one or more seasons and thus provided the data on which this study is based. It is our hope that the results will help to point the way to the maintenance and improvement of their sport.

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I INTRODUCTION

SUMMARY

Many different methods have been used for collecting data on angling effort and catch, and each is suitable for particular circumstances. In the present study it was decided to obtain information about:

(1) The state of fish stocks.
(2) The size and nature of the fishing effort.
(3) The size and distribution of the angling catch.
(4) The effect of regulations.

Ranging staff could not be used to collect the data since many districts are too incompletely covered for this purpose. Voluntary co-operation had therefore to be relied upon, and anglers were asked to maintain fishing diaries on standard forms and to return them for analysis at the end of the season.

The diary forms used generally asked for information on the date, water, and locality fished, the time of day and number of hours spent fishing, the number, species, and size of any fish killed, and the number of fish returned to the water alive and whether they were above or below the legal size limit. Length has been used throughout as a measure of the size of fish, as it is believed that more accurate figures will be provided by anglers for this quantity than for weight.

RELIABLE data regarding the yield have long been recognised as necessary to provide a basis for effective methods of fisheries management. In many countries more or less efficient schemes for obtaining these data for the commercial fisheries of the sea have been in operation since about the beginning of the century. Fresh-water fisheries, which in most countries are mainly sport fisheries, have usually lagged behind in the collection of these data. This has been partly because the need for the information was less obvious and partly because of greater difficulties in collecting it. Although some private or commercially operated sport fisheries have, for their own purposes, maintained records for a longer time, it is only within about the last twenty years that fresh-water catch statistics have been collected from public waters either on a national scale or as part of definite research programmes.

Schemes for the collection and utilisation of catch data can be roughly divided into two categories: intensive and extensive. Intensive schemes have as their object the collection of as much information as possible about the catch obtained in a particular area or from a particular fish stock. It is generally desired not only to obtain the most complete record possible of all fishing done in the area, but also to cover as many aspects as possible, e.g., sizes of individual fish, methods used, time fished, etc. To get these data it is necessary to contact as many as possible of the anglers fishing the waters concerned, and in many such studies one or more observers have been stationed on the water for all or most of the angling season. Schemes of this kind can usually be operated efficiently on waters where there are

only a few access points and where these can be easily kept under observation. One of the earliest intensive schemes was that begun by Mottley on Paul Lake, British Columbia, in 1932 (Mottley, 1940). Since that time a great number of similar studies have been undertaken, especially in North America. In New Zealand the first intensive collection of catch data was that organised by the North Otago Anglers' Club on the Kakanui River in the seasons 1932–33 to 1937–38. The results were not used to provide an estimate of the total catch from this river, and it is now impossible to attempt this. They were, however, used in conjunction with scale studies to examine the effect of the angling catch on the maintenance of the stock (Parrott, 1934). More recently an intensive scheme for the collection of angling catch data was carried out as part of the detailed study of the brown-trout population of the Horokiwi stream (Allen, 1951).

In extensive studies the object is to obtain as much information as is practicable about the catches from a relatively wide range of waters. In these circumstances the resources available both for collecting and for analysing the data inevitably make it necessary to limit severely either the completeness with which anglers are contacted, or the comprehensiveness of the information obtained from each angler, or both. The degree of supervision which can be given to the actual recording also tends to be reduced, with a consequent loss in reliability. Special checks by other techniques can, however, be used to test the reliability of the results. It is necessary in planning any extensive scheme to decide in advance on the balance which is desired between these three factors of completeness, comprehensiveness, and reliability, and then to select from the various possible techniques one which will give results with the required characteristics. Among the earliest of such schemes was that of the Michigan Conservation Department, which was begun in 1927 (Michigan Conservation Department, 1928) and which is apparently still in progress. The basis of this scheme is the recording by field officers of the relevant data concerning the anglers they contact in their normal duties. This method should enable very comprehensive results to be obtained with a degree of reliability limited only by the quality of the staff employed. On the other hand the amount of data may be small in proportion to the amount of fishing in the area, and its distribution will reflect the distribution of patrol activity more than that of the actual angling. Different methods have been employed by the Californian Division of Fish and Game, which has collected catch statistics on a large scale since 1936 (Calhoun, 1950). The basic object of this work appears to have been the estimation as accurately as possible of the total angling effort and catch and its distribution throughout the state, and detailed information about the catches on particular waters was therefore dispensed with. The first method adopted was to require all anglers when taking out a licence to fill in a questionnaire about their catches in the previous season. This was found to be unsatisfactory, partly on account of the delay of up to two years between the time of angling and the time at which the data became available for analysis, and partly on account of the unsatisfactory conditions under which the questionnaire had to be filled in (Hunter and Fry, 1940).

It was therefore replaced by a scheme in which questionnaires were distributed by post to a random sample of anglers at the close of each season. This gave more satisfactory results and about one-third of the cards sent out were returned. The main uncertainty of this method is the doubt as to how far the groups of anglers

sending in returns is representative of the whole. This was checked by means of a personal canvass of another random sample in 1948, and the results showed that no significant errors arose in this way.

These three methods – staff records, licence-application questionnaires, and postal questionnaires – or some variant of them have formed the basis of most of the extensive surveys of anglers' catch which have been recorded. The first extensive survey made in New Zealand did, however, employ a rather different method. This was started by the Otago Acclimatisation Society in the 1934–35 season; forms were distributed with all fishing licences at the beginning of this season, and anglers were asked to enter on them a daily record of their angling and to return the forms to the Society at the end of the season. This scheme was continued with a varying degree of response until the general scheme was instituted in 1947, and much of the data so obtained was analysed by Hobbs (1948).

In 1946 fresh-water fisheries research in New Zealand was reorganised and it was decided that the new programme should include the collection of catch statistics on the widest scale that would be practicable with the limited resources available. In determining the method to be adopted, consideration had to be given to the various kinds of information which can be derived from the basic data. The following seem to be the chief points which can be covered:

(1) The state of fish stocks, e.g., the size of fish caught, the abundance of fish as measured by catch per unit effort, and the quantity of undersized fish in the catch.
(2) The size and nature of the fishing effort.
(3) The size and local distribution of the angling catch.
(4) The effect of regulations either proposed or in force.

All of these points are of considerable importance to any attempt to manage fisheries effectively, and it was therefore decided to aim at a scheme which would provide data covering all these points even if this meant a reduction in the total quantity regarding any one point.

Data-collection schemes can be based either on recording by officers of the organisation concerned, or on recording by the anglers themselves. The resources available made it impossible to consider employing special staff for recording purposes, and in most parts of New Zealand the coverage of angling waters by enforcement officers is too incomplete to enable them to be used as the basis of a general scheme. It was evident, therefore, that in any effective scheme recording would have to be done by the anglers themselves. Here again there are two basic possibilities, either to ask anglers at the end of each season for information about their catches during the season, as in California, or else to try to get continuous records maintained throughout the season. While the first of these methods is likely to bring a response from a much greater number of anglers, it cannot provide detailed information regarding sizes of fish and rates of catch since the records are prepared from memory some months after the event. It will provide adequately only for the second and third points of the four points listed above. The conclusion was therefore reached that to obtain the desired data under New Zealand conditions it would be necessary to use a scheme in which anglers were asked to keep continuous detailed records throughout the season in a standard form and to return them for analysis at the end. Such a scheme would be on the lines of that already in use by the Otago Acclimatisation Society.

II THE BASIC DATA

SUMMARY

The distribution and collection of diaries, and local publicity were undertaken by the acclimatisation societies, and 16 out of 26 of these bodies took part in the scheme. Several of the remainder have virtually no fishing in their districts. The Marine Department was responsible for general planning and advice, and analysis of the results. In the Rotorua-Taupo and Southern Lakes districts, which are directly controlled by the Department of Internal Affairs, other methods of data collection were employed.

The average percentage of anglers co-operating ranged from less than 1 per cent to over 13 per cent in different districts. It was generally greater in districts containing less than 500 anglers than in the larger districts, and success depended upon the employment of a variety of publicity methods rather than upon the use of any particular and highly effective method.

Between one-third and two-thirds of the anglers keeping diaries dropped out each year, and the proportion tended to go up as the years went by. In these circumstances maintenance of an adequate number of diaries depended upon a sufficient number of new recruits being obtained each year. The number of recruits tended to be greatest in the first one or two years of the scheme and then to fall off slowly. The total number of diaries in each district therefore tended to rise for a time and then to fall, slowly at first and then more rapidly. The same course would probably have been followed by the total response from the whole country if the scheme had not been discontinued when the total number was about at its peak. The scheme was ended because it appeared that the additional data which could be obtained by continuance would add little to that already available and would not justify the expenditure and effort involved.

In the earlier years manual methods of analysis were used, but in the last two years the data were transferred to punched cards and analysed mechanically. Both methods had advantages and disadvantages.

1. COLLECTION

For the reasons discussed above the main method used in the data-collecting programme was the distribution and collection of standard angling diary forms, although other techniques were employed in districts where they were possible. The actual operation of the scheme had to be based on the present organisation of fresh-water fisheries in New Zealand. Although the central administration, including research, is in the hands of the Marine Department, local administration, including the collection and spending of licence fees and the provision of ranging

services is, in most parts of the country, controlled by a network of 26 acclimatisation societies. In two areas where there are many visiting anglers and only small resident populations, another Government Department, that of Internal Affairs, is the local administrative body.

Although the Marine Department initiated the diary scheme as part of its research programme, it was obvious that the detailed work of distributing and collecting diaries would be better performed by the acclimatisation societies who, through their licence-selling agents and field staffs, had direct means of contact with individual anglers. The Marine Department would, on account of its small staff, have to restrict its activities to stimulating the interest of acclimatisation societies in the scheme, providing technical advice on methods of operation, including the design of suitable forms, and analysing and reporting on the results. Preparations for a scheme on these lines were begun in 1946, and in two districts, Otago and Nelson, diaries were distributed for the 1946–47 season. On the basis of the experience gained in these areas, the general scheme was begun in 1947.

All acclimatisation societies were circularised early in the year. In the circulars the objects of the scheme were explained and the methods to be used were outlined. Further circulars were sent out in later years and every opportunity was taken to urge upon societies the need to collect data about their districts in this way. The general scheme was kept in operation until the end of the 1951–52 season. It was then discontinued since it had become obvious that the additional data which would come in as a result of continuation on existing lines would no longer justify the expenditure of time and effort involved. The seasons in which the scheme was in operation in each district and the number of diaries obtained are summarised in Table 1. The numbers placed before the names of the districts enable them to be identified in Fig. 1, which shows the arrangement of acclimatisation districts in New Zealand.

Table 1. The Seasons in Which the Scheme Was Operated and the Number of Diaries Obtained in Each District Compared With the Number of Licences Sold

District	Starting Year	Number of Seasons	Total Number of Diaries	Percentage Complete	Licence Sales	Percentage of Diaries
1. Ashburton	1948	4	29	91·1	735	0·99
2. Auckland	1948	4	105	98·2	1,716	1·53
3. East Coast	1947	4	15	93·4	71	5·28
4. Hawera	1948	1	14	92·8	222	6·31
5. Hawke's Bay	1947	5	47	100·0	605	1·55
6. Marlborough	1949	3	14	85·7	114	4·09
7. Nelson	1946	6	262	93·8	317	13·79
8. North Canterbury	1947	5	109	79·8	2,184	1·00
9. Otago	1946	6	452	97·5	2,109	3·57
10. South Canterbury	1947	5	59	96·6	1,280	0·92
11. Southland	1947	5	144	93·1	2,139	1·35
12. Taranaki	1947	5	28	96·4	311	1·80
13. Waimarino	1947	5	123	85·3	221	11·13
14. Wellington	1948	4	98	81·6	1,536	1·60
15. West Coast	1949	3	32	84·4	322	3·32
16. Westland	1950	2	7	71·4	63	5·55
	..	..	1,538	..	13,945	2·26

Fig. 1:

A. Acclimatisation districts which took part in the diary scheme.

B. Districts controlled by the Department of Internal Affairs in which data were collected by other methods.

C. Acclimatisation districts which did not take part in the diary scheme.

(The key to the numbers identifying the districts is given in Table 1 and on p. 11.)

It was found that the diaries included a certain number which had, apparently, been discontinued part way through the season as though the anglers concerned had for some reason stopped recording their catches. In most of the diary forms used in the later seasons, space was provided for the diarist to show whether his record was complete or incomplete. Since, however, this was not always provided, and when provided was not always filled in, it was often necessary to make a subjective judgment as to whether or not a diary was complete. The fifth column of the table shows the percentage of diaries which were adjudged complete. In order to show the varying degrees of co-operation given by anglers in different districts, the sixth column shows the number of men's whole-season licences sold in 1951–52, the last season of the scheme, and in the last column the average number of diaries obtained in all the seasons in which the scheme was in operation in the district is expressed as a percentage of the number of licences. For reasons explained below this figure is not the actual average percentage of licence holders who sent in diaries, but it does provide a useful measure of the degree of response and one that can fairly be used to make comparisons between the responses obtained in different districts.

The percentages given in the table tend to be reduced below the true averages by the general increase in licence sales during the period of the diary scheme. As Table 37 shows there was an increase in the number of licences sold by acclimatisation societies from 10,300 in 1947–48 to 14,800 in 1951–52, or about 40 per cent. On the other hand the numbers of diaries have been compared only with the numbers of men's whole-season licences. The holders of such licences are by far the most numerous class among anglers in general, and particularly among the diarists. A small, though indeterminable, proportion of diaries was, however, sent in by women and boys and by the holders of short-period licences, and this will tend to cause the percentages shown to be rather higher than the true figures.

Data were also collected in the districts controlled by the Department of Internal Affairs, Rotorua-Taupo (17) and Southern Lakes (18), although the high proportion of anglers visiting the districts for short periods only and the more numerous ranging staff made other methods appropriate. The results of this work will be reported elsewhere.

A small number of acclimatisation societies did not attempt the collection of catch data by the diary scheme, and their districts are shown blank in Fig. 1. These districts and the number of licences sold in them in 1951–52 were:

19	Bay of Islands	1
20	Hobson	0
21	Mangonui-Whangaroa	0
22	Stratford	121
23	Tauranga	114
24	Waiapu	13
25	Waimate	231
26	Waitaki	290
27	Wanganui	74
28	Whangarei	5

Some of these districts yield little or no trout fishing and sell few licences but others sell more licences than some of those districts which have actively taken up the diary scheme.

The West Coast Acclimatisation Society was formed prior to the 1951–52 season by the amalgamation of the Buller and Grey District societies. In the table the results for these two societies in earlier years have been combined with those of the new society in the final season.

As was explained above, the general scheme was started in the 1947–48 season, and about half the societies taking part began in that year and most, though not all, of them continued until the close in 1952. Recruitment to the scheme continued almost throughout, and in every season except the last, a few societies ran a diary scheme for the first time.

It is evident from the table not only that the different acclimatisation societies varied considerably in the alacrity with which they took part in the diary scheme, but also that where they did take part there was great variation in the degree of co-operation given by anglers. At one extreme more than one-tenth of Nelson and Waimarino anglers kept and returned diaries; at the other, less than one in every hundred Ashburton and South Canterbury anglers took part. An effort has been made to find the causes of these variations in order to determine the best methods of organising an effective diary scheme.

In an attempt to get detailed information on the techniques used and their effect on the anglers' response, a questionnaire was sent to all acclimatisation societies at the close of both the 1947–48 and the 1948–49 seasons. This questionnaire listed a number of possible methods of distribution, encouragement, and collection which could have been used and asked the societies to indicate which they had employed. The results were disappointing: it was impossible to detect any correlation between the methods used and the response obtained, although there was some indication of a general tendency for the best results to come from the districts where most methods were tried. It has, however, been possible to examine the effect of a few factors on the response by making use of other data as well as the replies to the questionnaire.

(a) Size of Societies

Table 1 itself shows one factor which appears to have influenced the degree of co-operation. This is the size of the society, the small societies generally obtaining a better response than the large ones. A natural division seems to fall at about the size of society which sells 500 licences. Among the eight societies selling less than 500 licences, only one, Taranaki, obtained diaries from less than 3 per cent of its anglers, and the percentage over the whole combined group was 6·74. Eight societies also sold more than 500 licences, and only one, Otago, where a long diary-keeping tradition existed, obtained more than a 3 per cent response, and the combined percentage was only 1·67, or slightly less than one-quarter of that obtained from the smaller societies.

(b) Method of Distribution

Two main methods of distribution have been used. In one, diary forms were given, or at least offered, to every angler when he bought his licence. In the other, diaries were distributed directly by the society or the officials of the society to anglers known to them or who asked for diaries. Both methods have given very variable final results, but there has been some consistency in the proportion of anglers under the second scheme who actually kept and returned their diaries. This

method was used in the following districts and seasons and the percentage of diaries returned was: Auckland (1948–49) 32·4; East Coast (1947–48, 1948–49) 25·0, 25·0; North Canterbury (1947–48) 20·7; Otago (1947–48, 1948–49) 47·3, 33·1; Southland (1947–48, 1948–49) 27·9, 37·8; Waimarino (1947–48, 1948–49) 50·0, 50·0. In these districts and seasons 864 diaries were individually distributed, of which 304 (35·2 per cent) were returned. When diaries are distributed in this way, between one-quarter and one-half, with an average of about one-third, are returned. The actual proportion of all anglers sending in diaries under this scheme is much more variable, so that the result seems largely to depend on the proportion who are individually contacted and offered diaries.

Under the other type of scheme, when all anglers are given or offered diaries, highly variable results have also been obtained, ranging from the high figures for the Nelson district, where this method was used throughout, to the low figures for North and South Canterbury, where it was used in most or all years.

(c) Competitions

At the beginning of the general diary scheme, prizes were offered in two districts for the best-kept diaries. In offering these prizes stress was laid on the fact that they would be given for completeness and accuracy of the results rather than for quantity of fish recorded. Since no external check on the accuracy of diaries is generally possible, and since the competition scheme had the definite danger of providing an incentive for sending in good-looking rather than accurate diaries, the response obtained in the districts where competitions were tried was carefully examined to test whether this did actually produce an improvement. In one district the number of diaries sent in after the 1947–48 season, when prizes were offered, was 14; in the two following seasons, when no competition was held, it was 15 and 17. In the other district prizes were offered in 1947–48 and 1948–49 and 38 and 36 diaries were sent in. After the competition was discontinued the number fell to 20 and 16 in the next two years, but rose again to 34 in 1951–52 without resumption of prizes. While the competition was running, the percentages of anglers who sent in diaries ranged between 1·3 and 1·7. These districts both sold over 500 licences and those percentages are only about the average for districts of this size even when no competition is held. These results lead to the conclusion that offering prizes for the best diaries does not bring about an increase in response at all sufficient to offset the disadvantages of the increased risk of inaccurate results.

(d) Secrecy

It seems to be generally believed that one of the major difficulties in obtaining a good response to a diary scheme is the natural reluctance of anglers to disclose just what they have caught and, particularly, where their favourite fishing spots were. Every opportunity was therefore taken to ensure, and to draw attention to the fact, that individual results were never disclosed. The diaries, after collection by an acclimatisation society, were sent in bulk to the Department, where the results were extracted and analysed. The diaries were then sent back to the societies for return to their owners. The published results of the analysis contained only overall average figures for anglers' performances, and the combined results for each of the important waters were given without any specification of localities. As a

result of these precautions, anglers seemed generally to accept the fact that the diaries were handled in a confidential manner, although in some areas persistent rumours that the detailed results were being used in other ways proved difficult to overcome. In one district exceptional precautions were taken to make evident the anonymity of the diaries. In 1950–51 and 1951–52 diaries issued by this society had no space for the owner's name, but were identified solely by a printed serial number corresponding to the number of the licence with which they were issued. In these two seasons the average number of diaries returned in this district was 36·5, while in the three previous seasons it was 12·0. In this district also no separate results for individual waters were made public. While the figures for numbers returned suggest at first sight that the additional secrecy precautions had had considerable effect, it must be realised that the new scheme adopted in 1950–51 also gave more efficient distribution and ensured that every angler received a diary form. Even under this scheme the average response (1·7 per cent) was only about half that obtained in another major district, Otago, where no special precautions were employed. In other districts it was, of course, always possible for an angler who did not wish to disclose his identity to send in a diary without filling in the space for his name and address. In practice, less than one per cent of the anglers who sent in diaries did this.

(e) Personal Contact

General considerations suggest that personal contact with individual anglers and explanation of the objects of the diary scheme and the need for their co-operation would help to increase the degree of response. The higher response obtained in the smaller districts rather supports this view, since a greater degree of personal contact between the anglers and the officers and councillors of the societies could be expected in these districts. While it is generally difficult to measure the extent of this effect, two activities were undertaken which could be considered as increasing the personal approach in circumstances which enabled the effect on response to be tested.

During the 1950 close season, about one-third of those anglers in the Nelson district who had not sent in diaries that year were interviewed. The main object was to get data on the total catches of a random sample of anglers, but those interviewed were all urged to co-operate in the diary scheme and its objects were explained to them. About 80–90 per cent said they would keep a diary during the coming season. Of the 89 anglers thus contacted only 9 (10·1 per cent) kept and returned a diary in 1950–51. It is difficult to measure exactly the number of 1950–51 anglers who had not kept a diary previously and who were not contacted during the close season. It is estimated that there were about 139 such anglers, and of these 19 (13·7 per cent) returned diaries for the 1950–51 season. The percentage of diaries was therefore actually less from those anglers who were interviewed although the difference is not statistically significant.

Each year, the diaries were returned to their owners through the local acclimatisation societies, and a report on the district results was supplied to the society for publicity purposes. In 1951 copies of the district report were enclosed with each diary together with a letter thanking the diarist for his co-operation and asking him to continue in the coming season. Of the 329 recipients of these letters who could be traced, 157 (47·7 per cent) did not continue their diary keeping in the 1951–52 season. A comparison may be made with the previous year when this

additional method of approach was not used. The number of diarists in 1949–50 was 295, and 131 (44·3 per cent) of these did not continue in 1950–51. Again a slightly poorer result was obtained when the additional method was used although the difference is not significant. The results in this case may be complicated by the fact that it was announced at about the time the 1951–52 diaries were collected that the scheme was being discontinued, and this may have discouraged some anglers from sending in their diaries.

It appears that while the only two methods of increasing personal approach which could be tested did not lead to any increase in response, much additional investigation is needed if the best methods of obtaining angler co-operation in diary schemes are to be determined. For this it would be necessary to obtain much more detailed information as to the method employed in the various districts than has been possible under past conditions.

While few definite conclusions can be reached as to the efficiency of the methods used in running the diary scheme, it is desirable to make some further analysis of the response to provide a standard against which the success of future schemes can be compared. The number of diaries returned in any season depends upon:

(a) The number of anglers keeping diaries for the first time.
(b) The number of anglers who kept diaries in the preceding season and who continue to do so.

Table 2 summarises the available data on these two points for most of the districts which took part in the scheme. The societies have been grouped according to the season in which they began the diary scheme, because the data contain some indication of correlation between date of starting and the behaviour of the anglers. In particular, the proportion of diarists dropping out at the end of each season seems to be noticeably lower in the two districts which began in 1946 than in the others. The last column of the table shows the percentage of each year's recruits who kept a diary for only one year. In all groups this percentage shows a pro-

Table 2. The Number of Recruits to the Diary Scheme in Each Season, the Percentage of All Diarists Dropping Out, and the Percentage of Recruits Dropping Out After One Season's Diary-keeping

Starting Year	Number of Districts	Season	Recruits	Percentage Stopping	Percentage of Recruits Stopping
1946	.. 2	46–47	41	23·5	19·5
		47–48	76	34·7	43·4
		48–49	65	50·0	58·5
		49–50	60	31·7	45·0
		50–51	72	42·8	56·8
		51–52	32	..	..
1947	.. 5	47–48	70	66·7	60·0
		48–49	47	60·6	72·4
		49–50	33	62·2	75·7
		50–51	14	58·3	78·5
		51–52	31	..	..
1948	.. 3	48–49	61	40·3	37·7
		49–50	63	52·6	58·7
		50–51	42	52·8	64·3
		51–52	23	..	..

gressive increase with time, indicating that the anglers who most quickly responded to the request for diaries also tended to be most likely to carry on after the first year. In the two districts in the 1946 group this effect is very marked, and of the anglers who began in the first year about 40 per cent were still continuing to send in diaries six years later, when the scheme ended. Although the results show considerable irregular fluctuations from year to year the table shows that:

(a) The number of recruits is greatest in the first one or two years and then has a slight tendency to decrease.

(b) The proportion dropping out generally lies between one-third and two-thirds each season with a tendency to increase as time goes on.

These effects will lead to a fairly rapid building up in the number of diaries during the first few years which will cease when the number dropping out equals the number of recruits. This will be followed by a more gradual but accelerating decline as the number of recruits diminishes and the proportion dropping out increases.

Table 3, which shows the total number of diaries received from all diarists in each season, suggests that this pattern applies also to the total response and that the scheme was discontinued at about the time the downward trend was beginning. Under these conditions the maximum number of diaries which can be obtained in any season will depend as much upon the proportion of diarists continuing as upon the number of recruits entering each year. For a fixed number of recruits the number of diaries obtained annually after stability is reached will be inversely proportional to the fraction dropping out each year.

Table 3. The Total Number of Diaries Received From All Districts in Each Season

Season	1946–47	1947–48	1948–49	1949–50	1950–51	1951–52
Number of diaries	41	186	311	308	371	309

In compiling Table 2, only those districts were included in which the diary scheme was operated continuously from the time of starting until the general scheme ended. Where the individual angler could not be identified from year to year, the district could not be included in the table for obvious reasons. The Waimarino district was included in the 1948 group although shown in Table 1 as starting in 1947 because it began to operate a general scheme only in 1948. In the 1947–48 season only a very small number of specially selected anglers were asked to keep diaries in this district.

The total amount of data obtained from the diaries is summarised in Table 4. The figures given for days fished and for fish returned and kept are those actually shown in the diaries. The figures for hours are those shown in the diaries plus a small correction for the recorded days for which hours were not given. This correction was made by determining for each district the average length of the recorded fishing day to the nearest half hour and by multiplying the number of days with unrecorded hours by this figure. The number of fish shown as kept includes all such fish whether or not their lengths were recorded. As will be shown in a later section, there was in all districts a small proportion of the recorded fish for which no lengths were given.

Table 4. The Total Recorded Number of Days and Hours Fished and Fish Caught in Each Acclimatisation District in the Whole Period of the General Diary Scheme

District	Days	Hours	Undersized Fish Returned	Takable Fish Returned	Fish Kept
Ashburton	548	1,868	203	..	1,073
Auckland	2,210	9,261	3,993	38	5,057
East Coast	200	829	119	30	325
Hawke's Bay	1,715	4,980	1,142	170	1,956
Hawera	371	1,244	345	64	761
Marlborough	282	700	34	68	375
Nelson	5,120	14,948	2,862	308	9,527
North Canterbury	2,243	8,294	984	160	3,523
Otago	11,819	52,044	18,594	48	38,221
South Canterbury	1,477	5,191	2,088	309	4,111
Southland	4,430	16,495	5,974	1,160	14,747
Taranaki	683	1,892	368	18	656
Waimarino	2,502	5,867	1,022	256	3,975
Wellington	2,188	6,804	1,716	173	4,281
West Coast	728	2,204	217	87	1,230
Westland	137	337	19	2	177
Total	36,653	132,958	39,719	2,878	89,956

While the diaries provided by far the largest part of the data, two other methods were used in some districts which provided some additional material. In three districts, rangers were instructed to record similar information regarding the anglers they encountered in their normal duties. The extent to which this was actually done varied greatly and the amount of material obtained in this way is summarised in Table 5.

In Otago a number of angling clubs exist and one of their major activities is the holding of angling competitions. In giving permission for competitions to be held, the Otago Acclimatisation Society has made a condition that full particulars of all fish weighed in are to be recorded and passed to the society. These records have been made available for analysis with the diary material and, as Table 5 shows, the amount of data obtained in this way is considerable.

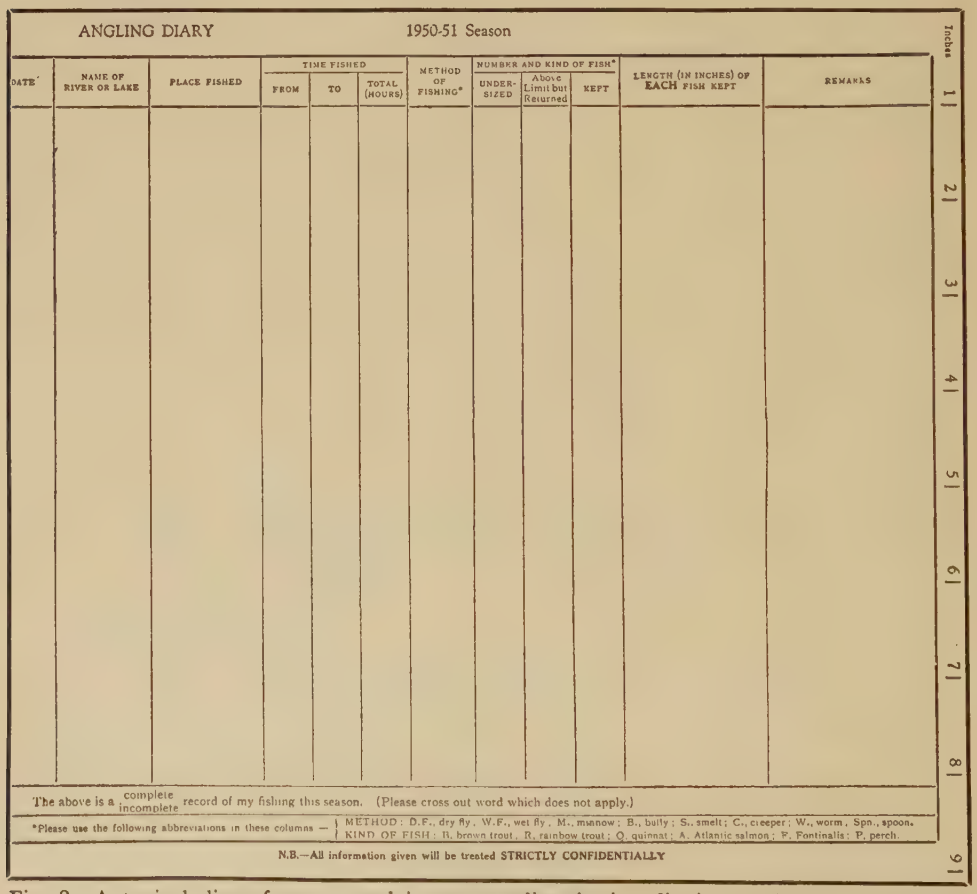
Table 5. The Total Number of Days and Hours Fished and Fish Caught and Returned and Recorded in Rangers' Reports and in Competition Records During the Period When the Diary Scheme Was in Operation

District	Angler Days	Hours	Undersized Fish Returned	Takable Fish Returned	Fish Kept
RANGERS' REPORTS					
Nelson	9	..	2	..	41
North Canterbury	266	693	55	7	166
Southland	1,282	3,452	1,209	10	4,205
Total	1,557	4,145	1,266	17	4,412
COMPETITIONS					
Otago	2,234	20,538	..	..	7,241

2. ANALYSIS

Although the printing and distribution of diaries was undertaken by the individual acclimatisation societies, the Marine Department provided advice as to the type of diary to be used, and gradually a standard form was evolved which was ultimately employed by most societies. In designing this the principal considerations involved were that it should be convenient for the angler to handle and use, that it should keep the information asked for to a minimum while including all that was essential, and that it should be convenient for analysis. A typical diary form is shown in Fig. 2. This was printed on light card and folded in three; the other side of the card (the outside when folded) carried space for the angler's name and address and a reasoned appeal for co-operation. The entries required from the angler were thus limited to the insertion of figures in the appropriate columns. Care and consistency in the order in which the headings were arranged was found to greatly facilitate analysis.

As the number of diaries returned annually increased, the difficulty of analysing them effectively with the limited staff available increased. The problem was made more acute by two steps which were taken to stimulate popular support for the



ANGLING DIARY — 1950-51 Season

DATE	NAME OF RIVER OR LAKE	PLACE FISHED	TIME FISHED: FROM	TO	TOTAL (HOURS)	METHOD OF FISHING*	NUMBER AND KIND OF FISH*: UNDER-SIZED	Above Limit but Returned	KEPT	LENGTH (IN INCHES) OF EACH FISH KEPT	REMARKS

The above is a complete / incomplete record of my fishing this season. (Please cross out word which does not apply.)

*Please use the following abbreviations in these columns — METHOD: D.F., dry fly; W.F., wet fly; M., minnow; B., bully; S., smelt; C., creeper; W., worm; Spn., spoon. KIND OF FISH: B, brown trout; R, rainbow trout; Q, quinnat; A, Atlantic salmon; F, Fontinalis; P, perch.

N.B.—All information given will be treated STRICTLY CONFIDENTIALLY

Inches 1 2 3 4 5 6 7 8 9

Fig. 2: A typical diary form as used in most acclimatisation districts; reduced to about half full size.

scheme. These were: (1) to return all diaries through the societies to the individual anglers who sent them in; (2) as far as possible to supply each society with a simple report on the results of each season's diaries before the next season opened. The first of these decisions meant that all the essential data contained in each diary had to be transferred to some other record for storage and subsequent analysis. The second decision made it necessary to carry out the transcription and primary tabulation of the data very rapidly; diaries were rarely received from societies before the second half of June, nearly two months after the season ended, and as far as possible reports were sent out by the middle of September.

In the earlier years of the scheme, purely manual methods of analysis were used. Each diary was copied completely on to a set of forms, one form being used for each water the angler had fished. By combining the totals on these forms in various ways, summaries were obtained of the essential features of each angler's effort, and of the fishing on each water. Ultimately district summaries were obtained. This method had the advantage that all the data were still available in easily legible form and, that, if desired, an individual diary could be reconstructed and examined for any desired feature. It had the disadvantage that analysis for any characteristic which was not made a basis of the original sorting (e.g., method of fishing) was very laborious.

Difficulties were experienced in obtaining adequate clerical staff for the operation of the manual scheme, and therefore in the last two years punched cards were used with Powers-Samas equipment. Diaries were examined and coded by trained fisheries staff and the data were then transferred to punched cards which were used for all subsequent analysis. In order to extract all the information desired, it was found necessary to prepare one card for each fishing day, and one card for each fish caught. Apart from the saving of staff time in the primary analysis, this method had the advantage that once the data were on the cards they could be rapidly sorted and analysed on bases different from those used in the original analysis. Its disadvantage was that it was less easy to locate and examine a single entry or diary, and that some data, such as those concerning localities fished, could not be conveniently coded, and were lost.

As a result of the two different methods of analysis, some of the minor analyses in this paper have had to be based on the data for only some of the years included in the scheme. For some purposes the 1947–50 data have been more available, but for others the 1950–52 data have had to be used.

In presenting the data for particular waters and districts, a few special problems have made it necessary to depart from the general practice of showing the results separately for each water in each district.

The Taranaki, Stratford, and Hawera acclimatisation districts have a number of rivers which run through two or even all three of them, and anglers from any of the districts are inclined to move freely throughout the area. In practice it was therefore often impossible to determine in which district a particular fishing day was spent, and in the analysis the whole area is therefore treated as one district. Since no diaries were received from Stratford anglers, it is referred to as the Taranaki-Hawera district.

In several places in New Zealand, rivers form the boundaries between acclimatisation districts. Three of these rivers are included in the present study. These are the Wanganui between Auckland and Waimarino, the Rakaia between Ashburton and North Canterbury, and the Mataura between Otago and Southland. In its

upper reaches the Mataura is the boundary between Southland and Southern Lakes, but since no data were available from Southern Lakes and practically all the Southland data apply to the part of the district that is contiguous with Otago, this river is treated only as the Otago-Southland boundary. In presenting the data for each of these boundary rivers the results for both districts are pooled, and the boundary rivers are listed together at the end of each tabulation rather than under the appropriate districts.

In Otago difficulty was experienced in distinguishing certain waters in the Waipori subsystem of the Taieri. On the Waipori river, the erection of the Mahinerangi dam has led to the formation of a lake and the division of the river into two sections. Careful scrutiny of many diaries seemed to show that anglers were using the terms "Waipori dam", "Mahinerangi dam", "Mahinerangi lake" and "Mahinerangi" for the artificial lake, "Mahinerangi river" and "Mahinerangi" for the river above the lake, and only "Waipori River" for the river below the dam. It was therefore impossible to distinguish with certainty between the lake and the river above it; the waters are continuous, and the records show no discernible differences between the stocks. All records referring to these waters were therefore pooled under the name "Mahinerangi-Waipori". The river below the dam appeared to be distinguished under the name "Waipori River". It is isolated from the upper system by the dam, and fish are markedly smaller. It is therefore treated separately in the tabulations.

III THE STATE OF FISH STOCKS

THE principal data relating to the state of fish stocks which have been extracted from the diaries are summarised in Appendix 1. The amount of data obtained from different waters varies widely, and it has been necessary to make an arbitrary selection of waters for inclusion in these tables. The criteria adopted have been at least 100 hours' recorded angling and 50 fish measured. It will be noticed that on some waters the number of fish measured is quite appreciably less than the total number caught. As in previous tables, the totals for hours have been corrected by an allowance for the days on which no time was entered on the diaries.

The three statistics most easily obtainable from the diaries are the rate of catch, the size of the takable fish and the proportion of undersized fish caught. These will be considered separately in the following sections.

1. RATE OF CATCH

SUMMARY

This is an index both of the abundance of the fish population and the reward anglers are obtaining for their efforts. When it is used for the first purpose it is necessary to be sure that the data are comparable in such features as type of water, methods used and angling skill. Rate of catch can be measured as number of fish per hour or per day. Catch per day is the anglers' natural unit but comparisons are complicated by the variable length of the fishing day. Catch per hour provides a standard time unit but it also is influenced by the length of fishing day. As days of increasing length are considered there is normally a decrease, rapid at first and then more gradual, in the average rate at which fish are caught. This effect is probably due to the lower average degree of concentration and proportionately greater time spent in rest and refreshment on a long day than on a short one. It is apparently not caused by the most skilled anglers, or those using the most effective methods, usually fishing a relatively short day, nor of shorter periods being fished at the best times of day, e.g., the evening rise. Catch per hour is therefore only a satisfactory index when the average length of the fishing day is comparable. As neither catch per day nor catch per hour is fully satisfactory, both have been used in summarising the results. Most waters give catches of between 1·0 and 3·0 fish per day and 0·25 and 1·0 fish per hour. Rates of catch are higher in the south-east part of the South Island (i.e., South Canterbury, Waitaki, Otago, and Southland districts) than elsewhere; here catches are generally greater than 2·5 fish per day and 0·75 fish per hour, while these figures are rarely exceeded in other parts of the country. These local differences may be partly due to variations in angling skill but they are mainly the result of differences in the fish stocks.

> The rate of catch for a particular water was significantly different from that for the same water in the previous season in about one-third of the cases studied. These differences are contributed to by changes in weather, angling skill of diarists, etc., and do not necessarily indicate changes in the state of the fish stock. It is believed that proportionate changes in rate of catch from year to year up to one-third may be ascribed to causes other than changes in the fish population.
>
> Unrecorded blank days, and inclusion as fishing time of all time elapsed between the beginning and end of fishing may have caused some systematic errors but these have been guarded against as far as possible.

The rate of catch is a form, appropriate to sport fisheries, of the catch per unit effort which is widely used in fisheries investigation as an index of the size or density of a fish population. As well as providing this index, it also gives a measure of the reward which anglers obtain for their efforts. In using this figure for comparative purposes it is necessary to be sure that the effort is of the same kind in each case, and that the measure of effort that is used is one which under a given set of conditions is as nearly as possible proportional to the catch. The criterion of kind of effort depends to a great extent on the purpose of the comparison, and particularly on whether it is to be used to compare fish populations or angling rewards. In comparing populations, variable features of the effort, such as diversity of angling skill, differences in method used, and seasonal effects, should be eliminated or allowed for by appropriate statistical techniques. Even when this is done, physical differences between different waters may be expected to cause corresponding differences in the relation between the rate of catch and population density. Any precise comparison is also rendered difficult by the uncertainty whether the relation in any specific case between rate of catch and population density is truly proportional. It seems generally reasonable to assume that the two quantities will vary in the same sense and by amounts of about the same order. Shetter (1950) has compared data from several sources and shown that for brook trout and brown trout in streams the rate of catch seems to be more closely related to the ratio between fish population density and angling density than to population density alone.

When the rate of catch is used as a measure of angling reward fewer problems arise with regard to the nature and efficiency of the effort. Provided sampling is adequately representative, the results for different waters may be directly compared to show the respective rewards obtained by anglers of the range of skill and using the particular methods which occurred on each water at the time of study. Similarly, comparisons on the same water between, for instance, different methods will show the relative rewards they give to anglers of normal skill under the conditions in which they are usually employed.

The rate of catch in sport fisheries is usually expressed as the average catch per individual angler per unit of time, although under special conditions other units such as the boat or party have sometimes been found more appropriate. Owing to the great variations in the total amount of angling done in a season by any one angler, the unit of time has normally to be either the day or the hour. The fishing day has disadvantages as a unit of time on account of its varying length. Not only does this vary from outing to outing for any one angler, but systematic differences between anglers, between waters, and even between districts may occur. To

illustrate the differences which may occur in the average length of day in different districts, the Waimarino district, where 1,979 recorded fishing days had an average length of 2·67 hours, may be compared with the Otago district, where 10,622 days averaged 4·47 hours. Since the number of fish caught in a day may be expected to have some relation to the length of time spent fishing, the average catch per day will reflect not only the frequency with which fish are caught, but also the length of the day. It will therefore not provide a very satisfactory index of the abundance of fish. As a measure of angling reward it has the same disadvantage that it does not provide a direct measure of the interval between captures, but, on the other hand, the day is the natural fishing unit and the total daily bag is the angler's natural unit of catch. The catch per day has therefore advantages as well as disadvantages as a measure of angling reward. Since each day is a separate unit unaffected by previous days, the mean catch may be expected to be independent of the number of days fished so that the total catch is proportional to the effort, or total number of days fished.

The alternative unit of time is the hour. This has the advantage of being of constant length so that the catch per hour gives a direct measure of the interval between captures. In this respect therefore the hour is preferable to the day as a unit in measuring both density of fish, and angling reward. Since, however, the angling day is of variable length and may commonly extend up to eight hours it is desirable to check how far the number of fish caught is actually proportional to number of hours spent fishing. Owing to the variations in the methods of analysis employed, only the results for the 1950–51 and 1951–52 seasons can be used conveniently for this purpose in most cases. Fig. 3 shows, for the six waters for which most data were available, the mean daily bag plotted against the length of the fishing day. To obtain the points plotted, the recorded days were grouped to the nearest half-hour, and each group for an odd number of half-hours was then combined with those for the succeeding whole number of hours. The mean length of day for the combined group was then determined and plotted against the mean bag. The figure shows that, at least for fishing days of up to 6 hours duration there is a close approximation to a linear relation between number of hours and number of fish caught. In each case the line, if extended backwards, cuts the catch axis at a point between 0·5 and 2 fish. It is interesting to note that in the Mataura River, which forms the boundary between the Otago and Southland Acclimatisation Districts and is fished by anglers from both sides, the two series of points based on the data obtained from the diaries collected from the two districts lie reasonably close to the same straight line.

If the graph of catch against length of day can be represented by a straight line as the data suggest, the curve for catch per hour against length of day will fit a rectangular hyperbola, with the rate of catch declining rapidly at first, and then more slowly, from an initial theoretical value of infinity for days of zero length and finally becoming asymptotic to a horizontal line at a level corresponding to the slope of the catch-day line. In several of the waters the points for very long days of eight hours and more seem to fall below the straight line which fits the earlier points. In such cases the rate of catch will continue to decrease as the length of day increases and will not level off to a constant value. An extreme example is shown by the Taieri River where the average daily catch remains constant despite the increasing length of day.

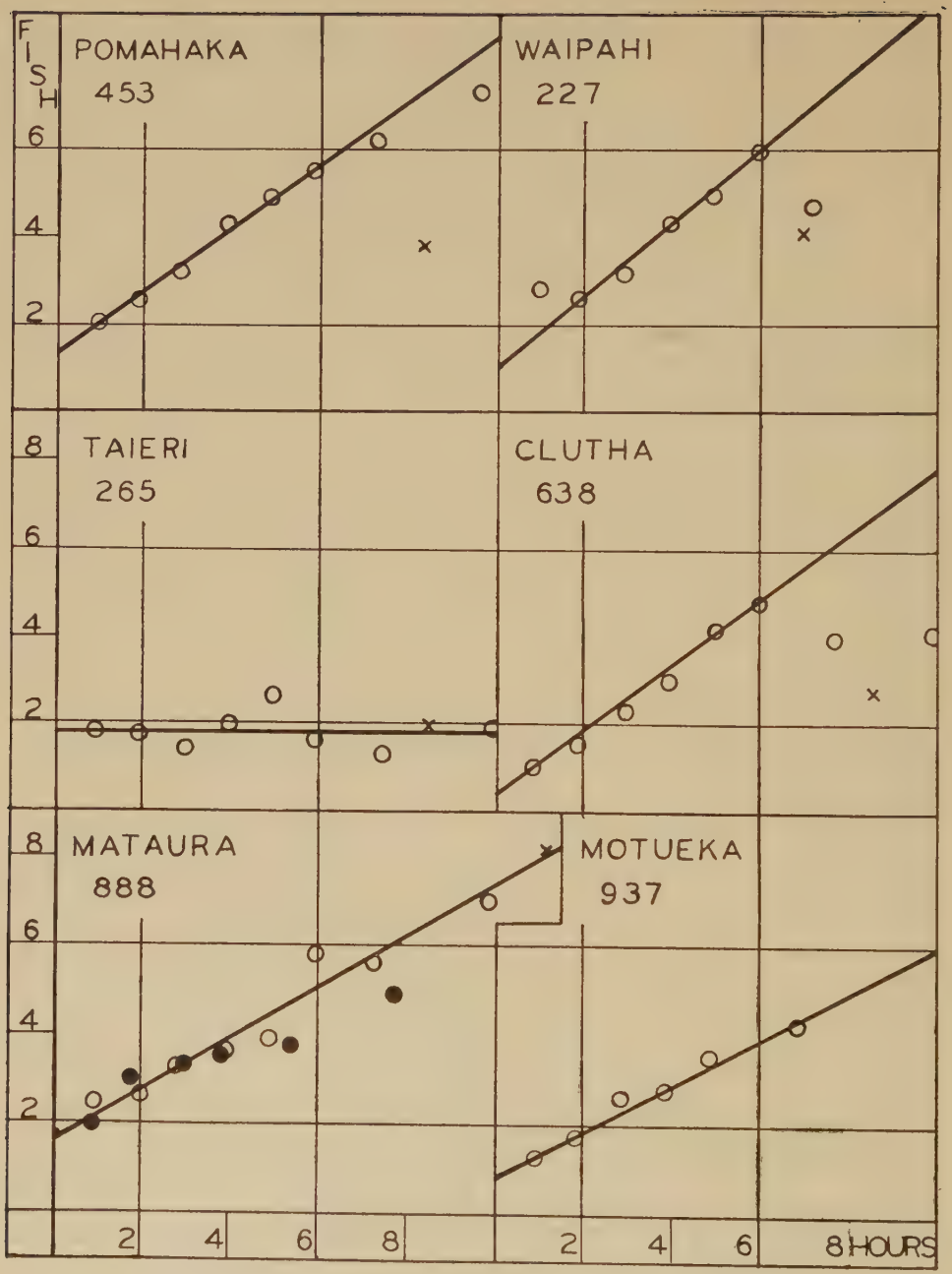


Fig. 3: The number of fish caught plotted against the length of the fishing day for six of the principal waters. The numbers below the names of the water indicate the total number of recorded days, × indicates competition results and, for the Mataura, ○ indicates Otago data and ● indicates Southland data.

Whatever the precise form of the actual curve, the data show clearly that there is normally a decrease, rapid at first and then more gradual, in the average rate at which fish are caught, as fishing days of increasing length are considered. It should be emphasised that this does not imply necessarily that in the normal fishing day the interval between catches increases as the day goes on; on this point there are no data. The data simply show that fish are caught more slowly on long days than on short days.

There are a number of factors which could contribute to this effect, and the influence of some of them can be studied by the examination of further data. To test the effect of the characteristics of individual anglers, the results for four anglers who recorded more than 200 days on a single water during the whole period of the diary scheme are plotted in Fig. 4. On account of the smaller size of the sample, the records are combined in groups of 2 hours, not 1 hour as in Fig. 3. It is evident that the same effect, a linear relationship cutting the catch axis at about 1 fish, occurs for individual anglers as it does for the combined results of many anglers on one water. It is possible that this effect could be contributed to by the nature of the method used if methods which were more in favour for use on long days were less effective than those used on short days. The best range of data available on this point is that obtained from the Mataura river. In Fig. 4 the mean catch is plotted against length of day for three of the principal methods used. The same reference line has been drawn with all three sets of points, and it is clear that the effect under consideration occurs whatever method is used and is therefore not due to the use of different combinations of methods on days of different length. Similar results are obtained if data from other waters are examined for the effect of method in the same way.

Another possible cause which may be considered is that arising from the part of the day in which the angler fishes. It is obvious that, in general, the longer fishing days must be started fairly early while the angler fishing only for a short period can start at any time, and might be expected often to be fishing for the evening rise. Unfortunately the Otago diaries, which often provide the greatest bulk of data on similar points, do not record the actual time of day fished and are therefore useless for the present purpose. The best data available are those from the Motueka river in the Nelson district. Records of 832 days have been analysed by dividing them into four groups according to whether the angler started fishing at or before 8 a.m.; after 8 a.m. and up to noon; after noon and up to 4 p.m.; and after 4 p.m. For each of these groups the points for mean catch plotted against time fished lie close to straight lines of about the slope shown for the Motueka in Fig. 3. That for the first period intercepts the catch axis at about 1·6 fish, the other three at about 1·0 fish. It does not appear, therefore, that in this instance at least there is any reason to suppose that difference in time of day contributes to the characteristic form of the relation between catch and time fished.

These results suggest that this characteristic relation, which results in a decrease in the average rate of catch as the length of the fishing day increases, can be regarded as a result of the intrinsic nature of angling and anglers' habits. This does not seem unreasonable, and a number of factors might contribute to the effect. There would be a natural tendency for the proportion of fishing time which an angler spent in rest or refreshment to increase as the length of the fishing day increased. This would reduce the proportion of effective fishing time, and so the rate of catch, since this has normally to be computed on the elapsed time between

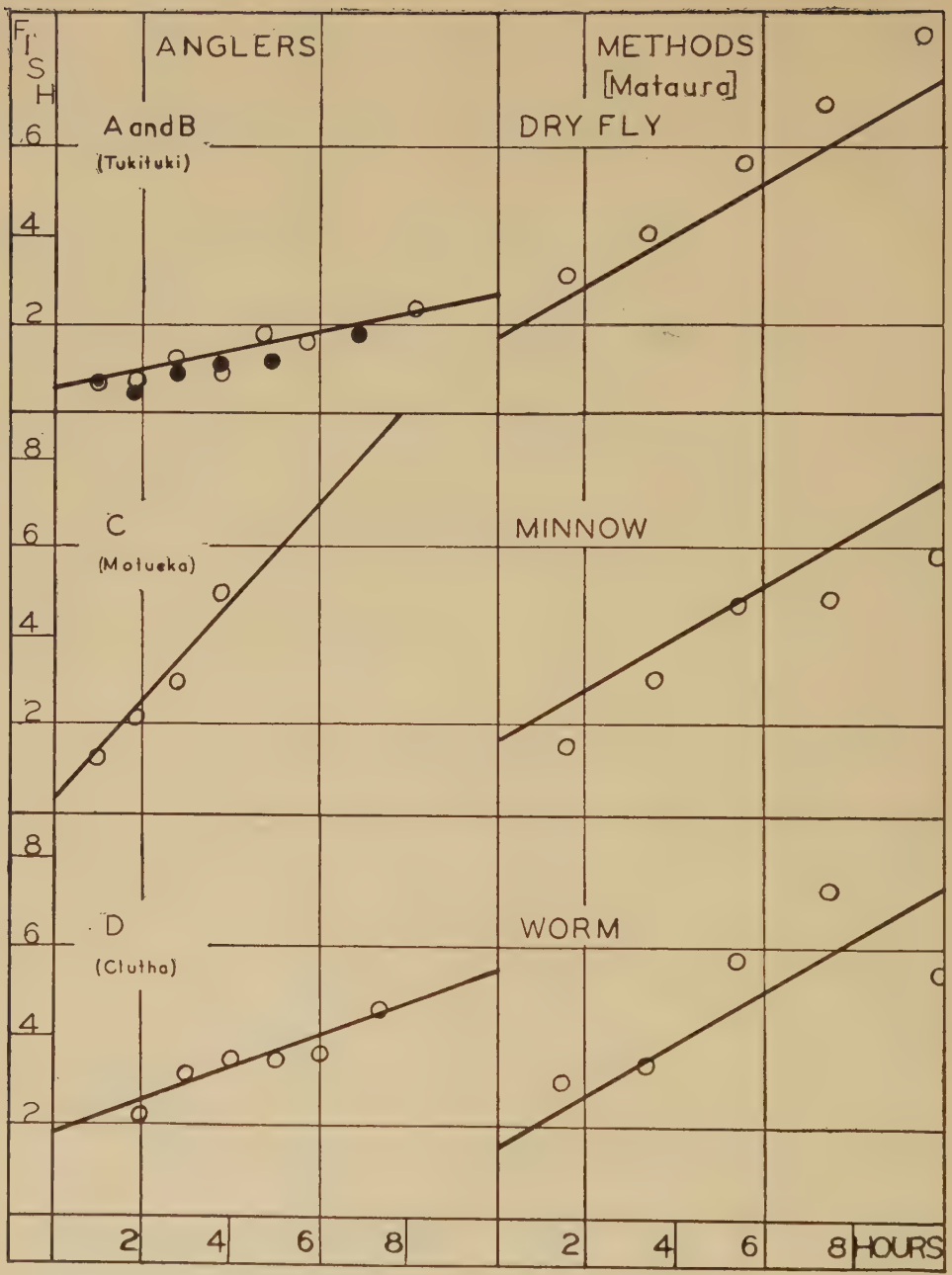


Fig. 4: The number of fish caught plotted against the length of the fishing day; in the left-hand section for four anglers who each recorded over 200 days' fishing on a single water, and in the right-hand section for the three main methods used on the Mataura. The same reference line has been drawn in all the panels of the right-hand section.

the beginning and the end of fishing. There would also probably be a tendency for the angler's concentration and energy to decrease during a long day and so reduce his angling efficiency. Further, an angler going out for a short time is more likely to select precisely a good place and a time, such as the evening rise, when the fish can be expected to be feeding freely, than is one who is going out for a half or whole day. It is also likely that some anglers go out with the intention of catching a predetermined number of fish, if possible, and that they stop when they have done so.

In Fig. 3 points are also plotted for competition results for the five Otago waters concerned. Competitions are normally fished for a relatively long day, generally between 8 and 10 hours, and it will be seen that the point for the average catch either lies close to the extension of the line fitted to the diary points or else is somewhat below it. The average catch per hour based on competition results will therefore be well below that based on diary results where the average fishing day is much shorter. This result is confirmed by study of the other Otago waters for which adequate amounts of competition and diary data are available. With a single exception, in which the amount of data is relatively small, the catch per hour in competitions is very much less than that recorded in the diaries. There are two factors which may help to cause the tendency for competition rates to be even less than those shown by diaries for days of similar length. Competitions are held on dates and at places decided long in advance, and therefore probably take place under relatively adverse angling conditions more often than does free angling when the angler can decide on his plans in the light of the prevailing conditions. The angling time as recorded for competitions also includes time spent in travelling between the actual fishing spots and the points of assembly and weighing-in; it will therefore be longer than the period actually spent in fishing.

Examination of the relation between length of fishing day and number of fish caught has shown that the catch is not directly proportional to the number of hours fished. Therefore, while it eliminates some variables, the catch per hour does not altogether fulfil the ideal requirements for a measure of the catch per unit effort. If the length distribution of the recorded days is reasonably similar in the series which are to be compared, the catch per hour will give a satisfactory basis of comparison. If, on the other hand, the days are of very different length in the various samples, comparisons of catch per hour are of very little value. Comparison between the catch per hour in diary records for one season, and in competition results for another, for instance, would be valueless as an indication of how the fish population or the angling reward had changed from one season to the other.

Thus, the only two measures of rate of catch which seem practicable, the catch per day and the catch per hour, both have certain advantages and certain disadvantages. The more appropriate one for use in any specific instance must depend on the nature of the data and the purpose of the comparison. In Appendix 1 both figures are given for each of the waters concerned and these results are summarised in Table 6. In most waters the catch per hour was between 0·25 and 1·0 fish, and 85 per cent of the waters included in the table fall within this range. For catch per day the usual range is 1·0 to 3·0 fish and this includes 70 per cent of the waters in the table. There is some variation amongst different parts of the country. The rate tends to be distinctly high in the small but important group of districts

Table 6. The Distribution of Rate of Catch Per Day and Per Hour in Each District for the Waters Included in Appendix 1

District	Fish Per Day										Fish Per Hour							
	0–0·5	0·51–1·0	1·01–1·5	1·51–2·0	2·01–2·5	2·51–3·0	3·01–3·5	3·51–4·0	4·01–4·5	4·51–	0·0–0·25	0·26–0·5	0·51–0·75	0·76–1·0	1·01–1·25	1·26–1·5	1·51–1·75	1·76–2·0
Ashburton	..	1	1	..	..	1	..	..	..	..	..	1	1	1	..	..	..	..
Auckland	..	..	..	3	4	2	3	1	..	..	..	5	7	1	..	..	..	..
East Coast	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..
Hawke's Bay	..	4	2	..	..	..	..	..	..	..	..	6	..	..	..	..	..	..
Marlborough	..	..	1	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
Nelson	1	1	2	9	3	..	..	..	..	..	..	3	10	3	..	..	..	..
North Canterbury	..	..	7	2	2	..	..	..	..	..	..	9	2	..	..	..	..	..
Otago	..	..	2	2	3	8	1	4	1	5	1	5	3	11	3	1	..	2
South Canterbury	..	..	..	1	1	..	2	2	..	1	..	1	..	1	3	1	..	1
Southland	..	..	..	1	2	2	2	1	2	4	..	1	4	2	5	2	..	..
Taranaki-Hawera	..	1	..	2	..	2	..	1	..	..	..	1	3	2	..	..	..	..
Waimarino	..	..	2	4	..	..	..	..	..	..	..	1	5	..	..	..	..	..
Waitaki	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..
Wellington	..	..	2	4	2	1	..	1	..	..	..	2	4	3	1	..	..	..
West Coast	..	..	2	1	1	..	1	..	..	..	..	1	3	1	..	..	..	..
Westland	..	..	1	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
Otago-Southland	..	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..
Ashburton - North Canterbury	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..
Auckland-Waimarino	..	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..
South-east	..	..	2	4	6	11	5	7	4	10	1	8	7	15	11	4	..	3
Others	1	6	20	29	12	5	5	3	..	..	..	31	38	11	1	..	..	..
Total	1	6	22	33	18	16	10	10	4	10	1	39	45	26	12	4	..	3

lying in the south-east corner of the South Island. These districts are South Canterbury, Waitaki, Otago, and Southland. In the 49 waters in this area 33 (67 per cent) gave rates per hour greater than 0·75 fish, while in the 81 waters from the rest of New Zealand only 12 (15 per cent) gave rates greater than 0·75. The distribution of the daily rate of catch shows a similar effect, although it is complicated by the variation between districts in the normal length of the fishing day. In the south-eastern group 37 (75 per cent) of the waters yielded over 2·5 fish per day, while in the remaining districts only 13 (16 per cent) waters gave average daily bags of more than 2·5. Within these two main areas no further significant differences in average rates of catch can be detected.

To a large extent the difference between the south-eastern area and the remainder of New Zealand reflects a real difference in density of stock but it may also be contributed to by differences in angling skill. This is difficult to measure objectively but numerous contacts with anglers give the impression that the general level of angling skill is higher in the south-east than elsewhere.

These differences between large areas, as well as some of the greater differences between individual waters shown in the appendix, seem to represent real differences between the respective stocks, but the sampling errors involved are such that it is difficult to assess precisely the degree of difference to which significance should be attached. In a previous paper (Allen, 1955) it has been shown that, at least in New Zealand, the distribution of daily catches in any reasonably homogeneous sample is such that log $(n + 2)$ is normally distributed, where n is the number of fish in the daily catch. From this distribution the significance of the differences between mean daily bags can be calculated.

Table 7 shows the mean rates of catch per day and per hour for each season for the eleven waters which gave the largest amounts of data. The significance of the differences in the rate for successive seasons has been tested, and those seasons giving rates which are significantly different at the 1 per cent level from those of the previous year are marked with an asterisk. A significant difference appears in nearly one-third of the comparisons for fish per day and in this proportion therefore the hypothesis that the two successive samples were drawn from the same population of bags should be rejected. This is not evidence that the state of the fish population has changed in these cases from one season to the next. The mean daily catch as recorded depends not only on the abundance of the fish population but also on many other factors, including the skill of the particular anglers contributing the record, the weather conditions, and the length of time fished on each recorded day. A significant change in the mean daily bag between two seasons simply implies that there has probably been a change in some or all of a group of these and similar factors; and the abundance of the fish population is one of the factors in this group.

The nature of the distribution of the daily bag is such that the catch per hour will be similarly distributed and similar methods can therefore be used to determine when the difference between two mean rates is mathematically significant. When this test also is applied to the data in Table 7, a very similar proportion of significant changes is found although not all of these occur in the same seasons. Since all the factors mentioned above can influence the hourly rate of catch, and the length of day is an additional variable, no further conclusions can be drawn from the catch per hour than from the catch per day as to the changes in the abundance of the fish stock.

Table 7. Changes in Daily and Hourly Rates of Catch From Season to Season in Some of the Principal Waters. Asterisks Indicate That the Difference From the Previous Year is Significant at the 1 Per Cent Level

District	Water	Fish Per Day											
		1946–47		1947–48		1948–49		1949–50		1950–51		1951–52	
		Days	Rate	Days	Rate	Days	Rate	Days	Rate	Days	Rate	Days	Rate
Hawke's Bay	Tukituki	..	..	126	1·29	186	1·26	358	1·52	212	0·73*	177	1·25*
Nelson	Buller	47	2·67	133	1·71*	173	1·78	152	1·76	111	1·59	91	1·21
	Motueka	111	1·85	208	1·91	285	2·42*	326	2·21	507	2·36	470	2·17
Otago	Clutha	98	2·92	142	3·36	222	2·82	149	2·88	330	2·78	319	3·21
	Pomahaka	144	2·77	391	3·79*	470	4·11	543	4·23	493	4·23	342	3·78*
	Taieri	92	2·61	208	2·36	212	2·03	126	1·13*	135	1·42	142	2·14*
	Waipahi	69	1·87	155	4·24*	263	4·08	183	3·83	145	4·93*	83	3·51*
Otago-Southland	Mataura	63	2·57	564	3·64*	418	3·27	436	4·16*	603	3·71*	473	4·39*
Southland	Aparima	..	..	121	5·16	173	3·47*	122	4·13	146	3·64	220	3·23
	Oreti	..	..	135	3·19	152	2·88	39	3·69	34	3·44	126	2·59
	Waiau	..	..	154	2·69	225	1·54*	144	2·65*	155	2·94	336	2·37*

District	Water	Fish Per Hour											
		1946–47		1947–48		1948–49		1949–50		1950–51		1951–52	
		Hours	Rate	Hours	Rate	Hours	Rate	Hours	Rate	Hours	Rate	Hours	Rate
Hawke's Bay	Tukituki	..	..	473	0·36	619	0·42	1,166	0·54	497	0·33*	521	0·44
Nelson	Buller	188	0·66	469	0·52	485	0·64	512	0·53	311	0·57	310	0·38*
	Motueka	350	0·59	676	0·61	841	0·87*	968	0·76	1,428	0·86	1,287	0·82
Otago	Clutha	503	0·57	776	0·62	931	0·67	703	0·59	1,428	0·65	1,550	0·66
	Pomahaka	701	0·57	1,675	0·82*	2,183	0·89	2,144	1·07*	2,050	1·00	1,361	0·97
	Taieri	450	0·53	1,307	0·38*	1,373	0·38	893	0·16*	718	0·27*	537	0·59*
	Waipahi	353	0·37	806	0·82*	1,200	0·89	860	0·81	683	1·05*	342	0·85*
Otago-Southland	Mataura	297	0·55	2,115	1·00*	1,442	1·02	1,888	0·97	2,499	0·91	2,303	0·93
Southland	Aparima	..	..	411	1·65	485	1·23*	501	1·03*	464	1·30*	785	1·04*
	Oreti	..	..	642	0·70	615	0·89*	176	0·83	136	1·23*	634	0·57*
	Waiau	..	..	474	0·89	770	0·51*	492	0·78*	449	1·02*	1,253	0·68*

Table 8. The Mean Hourly Rates of Catch in Each Season Determined From Data Obtained From Different Sources. Results for the Mataura and Wanganui Rivers

River	Source of Data	1946–47		1947–48		1948–49		1949–50		1950–51		1951–52		Total	
		Hours	Rate	Hours	Rate	Hours	Rate	Hours	Rate	Hours	Rate	Hours	Rate	Hours	Rate
Mataura ..	Otago diaries ..	297	0·54	980	0·81	599	0·81	1,217	0·96	1,813	0·94	1,596	0·86	6,504	0·87
	Otago competitions	249	0·51	357	0·79	441	0·72	312	0·78	218	0·67	..	..	1,577	0·71
	Southland diaries ..	..	..	1,135	1·16	843	1·17	671	1·00	686	0·84	717	1·11	4,052	1·07
Wanganui ..	Auckland diaries ..	..	..	..	..	..	..	324	0·47	217	0·29	225	0·61	766	0·46
	Waimarino diaries ..	..	..	..	..	..	..	586	0·76	203	0·73	227	0·58	1,016	0·72

From two rivers, the Mataura and the Wanganui, data can be obtained from more than one source, so that it is possible to obtain some indication of the range of variation from season to season when variation in fish stocks is eliminated. Both these rivers form boundaries between acclimatisation districts, between Otago and Southland, and between Auckland and Waimarino, respectively. They are therefore each fished by two groups of anglers who fish the same water but return their diaries through a different acclimatisation society according to the bank on which they live. Additional data are available from the Mataura from the records of angling competitions held there. Table 8 summarises the seasonal results which have been obtained from the various sources for each of these waters. The differences in the combined means for the different sources arise, at least in part, from differences in length of the fishing day. Fig. 4 showed that, on the Mataura, the mean daily bags for days of different length gave a good fit to the same straight line whatever the source of the data. Table 8 shows clearly that, for both rivers, the changes from season to season follow quite different patterns for the different sources of data. There is thus no evidence that variations in the fish stock have contributed to the changes which appear. These can therefore be ascribed to random fluctuations together with the effect of the uncontrollable factors mentioned above.

Since there is no indication of any continuing trend, these results can be used to given an approximate indication of the degree of variation from season to season which may arise in this way. To do this the rates for each source in each season have been expressed as proportions of the overall mean for that source. The resulting proportional values have been combined in a single distribution which has, of course, a mean of 1·00. The standard deviation of this distribution is about 0·17. As the distribution is asymmetrical, being strongly positively skewed, it is not practicable to work out precise fiducial limits, but it appears likely that variations of up to about one-third may occur in the hourly rate of catch from season to season without it being necessary to ascribe them to fluctuations in the state of the fish population.

As well as the chance effects, the rates of catch as determined from the diary data are subject to certain systematic errors which may, in some instances, have considerable magnitude but which are very hard to estimate.

One of these is the difference, if any, between the actual time spent fishing and the time shown on the diary as elapsing between starting and finishing times. Most diaries contained a column for "time fished" as well as starting and finishing times, and where this contained a different figure from that obtained by subtraction it was obvious that the angler himself had made the necessary correction. This was comparatively rare and usually the total elapsed time had to be taken as the time fished. Any difference between the two would cause an error in the calculated rate of catch. Even when the full circumstances are known it is, however, often difficult to decide precisely what is fishing time. Is the dry-fly angler sitting on the bank, smoking, and watching for a fish to rise, fishing or not? The only practicable solution seems to be that adopted, to take all elapsed time as fishing time unless the angler himself specifically excludes some of it. It must be realised that this will, however, produce a tendency for the rate of catch to be subject to reduction by a systematic error which will increase with the length of the fishing day and with the activity of the method used.

The other apparent source of systematic error lies in the failure of a certain number of anglers to record blank days. Although every effort has always been made to impress upon anglers the necessity of recording all days fished whether or not

anything is caught, there is a very natural tendency for diarists to overlook some blank days in writing up their diaries. The extent of these omissions seems to have varied considerably from district to district. Unrecorded blank days will lead to a low figure for total hours and hence to a high estimate of rate of catch. It will therefore have the opposite effect to that produced by the other source of systematic error, failure to allow for rest periods.

2. SIZE OF FISH

SUMMARY

In most cases the lengths of fish were recorded to the nearest inch. Some degree of bias in favour of even numbers generally occurred but probably had little effect on the mean lengths. The summary of the principal results (Appendix 1) shows only the mean lengths, but except when truncated by the size limit, the size-distribution curve is usually fairly symmetrical about a peak value. The decrease at sizes less than the peak in the number of fish caught is believed to be due to some aspects of their behaviour which render them less available to the angler. The reduction above the peak size probably reflects the actual structure of the population. On a log-natural plot this part of the curve is usually almost linear, with a slope corresponding to a ratio between the number at any inch and that of the next inch of 1 : 0·35 to 1 : 0·6. In large rivers where the nature of the trout population varies in different parts, the slope may be less steep, i.e., the lengths of fish caught are spread over a greater range.

Variations in mean length from year to year are probably not due to variations in the population if less than about 1 inch. They are due partly to sampling errors and partly to variations in factors which may affect the size of fish caught, e.g., method of fishing, water conditions, and places fished.

Plotting average length against rate of catch reveals a definite inverse relation. This effect is accentuated to some extent by local variations in the size limit, since, for any water, lowering the limit will decrease the average size and increase the rate of catch. This effect is only secondary and the inverse relation remains when the effect of size limit is eliminated. In the South Island, waters with large average size and low rate of catch (type B) predominate in the north and west, and those with small size and high rate of catch (type A) in the south and east. The difference seems to be correlated with the nature of the terrain, type A populations being found in country of low relief and type B where relief is high. In major rivers type B populations tend to occur in the headwaters among the mountains, while type A occurs in the open alluvial valleys. Type B populations are also frequently found in the tidal reaches near the mouths of major rivers, but these are probably produced by different environmental factors from those operating in the headwaters.

The weight of fish caught per hour is generally between 0·5 and 2 lbs. In the South Island yields of less than 1 lb. per hour are obtained mainly from two small areas, one in Nelson and one in North

Canterbury, and one larger area in south-east Otago. The last seems to be associated with the occurrence of schist.

In the North Island the distribution of yield and population type is more irregular, possibly as a result of the more complex topographic and geological situation.

Most of the diary forms issued to anglers laid down no standard of accuracy to which fish were to be measured, but it was found in practice that the majority of anglers appeared to measure their fish to the nearest inch. Some anglers recorded lengths to the half-inch or quarter-inch but these were comparatively few, and in the final tabulation for analysis the inch was used as the standard subdivision and measurements which included fractions were allocated to the nearest integer, or in the case of half-inches, to that immediately below the recorded length.

In some waters, where a few anglers had apparently relied on estimation of length, a bias in favour of even numbers appeared. Exact estimation of the extent of this bias is made difficult by the diversity in shape of the size-distribution curve for different waters and particularly by the great degree of truncation which occurs when the average size is not much greater than the size limit. The technique adopted has been to compare the actual recorded size distribution with a smooth curve fitted to these points by eye. The actual recorded totals for odd and even lengths are then compared with the expected totals by means of the chi-square test. To examine the extent to which even-number bias occurs in the data the detailed size distributions which were published elsewhere (Allen, 1954, Table 4) for seven waters having various types of distribution have been used. In every case the actual number of even lengths was in excess of expectation. The difference is not significant in the Awakino, Maitai, and Leith, where the samples are relatively small, but in the other waters it is greatly in excess of the 1 per cent level of significance. An outstanding example is provided by a series of lengths of 1,723 fish recorded from a single river by an acclimatisation society officer. These results are set out in Table 9, and the even-number bias is obvious. Chi-square is 188 and it is evident that the method of estimating length was subject to a large systematic error.

Table 9. The Percentage Length Distribution for 1,723 Fish Recorded by One Observer From One River. The Results Show Evident Even-number Bias

Length (Inches)	Percentage	Length (Inches)	Percentage
12	16·0	13	8·6
14	21·5	15	10·7
16	21·3	17	8·2
18	8·8	19	2·7
20	1·0	21	0·9
22	0·1	23	0·1
	68·7		31·2

Although it appears that some degree of even-number bias occurs frequently in the diary records, it probably does not seriously affect the value of the mean length, since the bias is probably produced by misreading, either upwards or downwards, to the nearest even number. The number of fish in each two-inch group will tend to remain the same. A significant effect on the mean is only likely to occur when the lower limb of the curve is cut off by the size limit, and the remaining part slopes steeply from the beginning. It is interesting that among the waters studied this type

of distribution was found only in those (Maitai and Leith) which appeared to have no significant even-number bias.

The original data provide useful information as to the size distribution of the fish caught and retained by anglers in each water. The mean lengths tabulated in Appendix 1 present only part of this information although they do provide a rough comparison of the trout stocks of different waters. Although publication of the detailed size distribution for each water is not practicable, the diary data show the main characteristics of this distribution. If the size distribution of the fish taken by anglers from a water in which the size limit has little effect is examined, it is normally found that fish of one particular size range predominate and that fish larger or smaller than this range become progressively scarcer. A number of such distributions are shown in Figs. 5, 6, and 7, the percentage frequency being plotted on a logarithmic scale.

In the waters shown in Fig. 5 the average size is relatively high and the ascending limb of the curve is correspondingly well developed and clear of effects produced by the size limit. Where the gap between the size limit and the modal size is less, truncation of the lower end of the curve occurs as in the waters shown in Fig. 6.

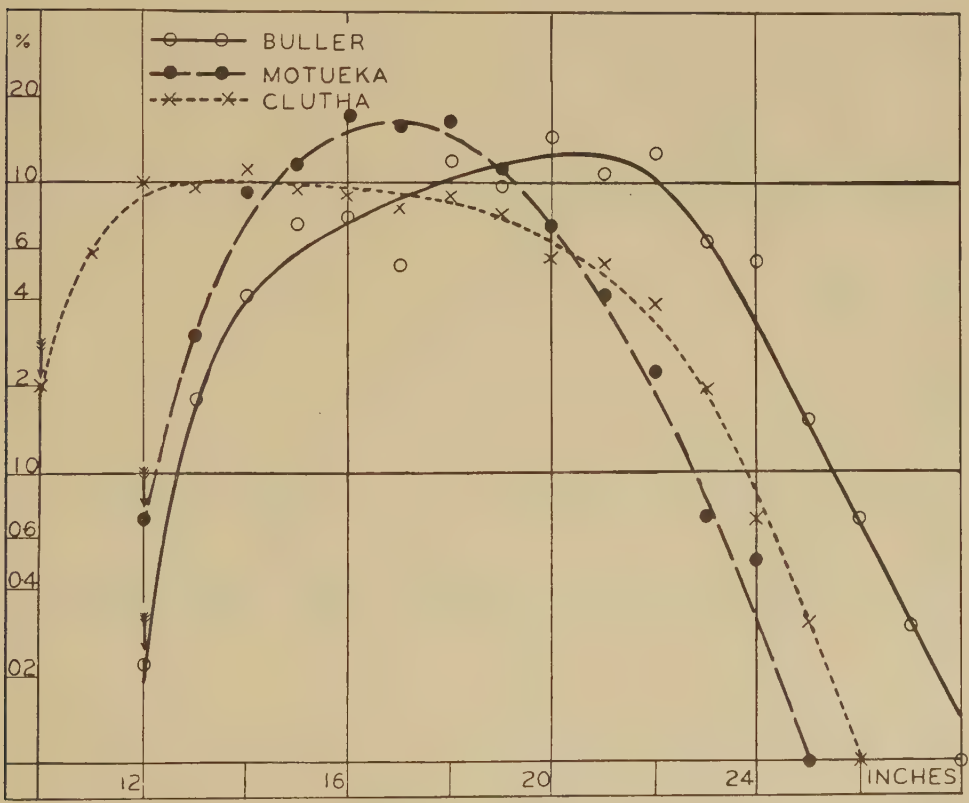


Fig. 5: The size distribution of fish taken by anglers in three rivers in which the most common size was much greater than the size limit. The arrows indicate the limiting size for each water.

In other respects the curves are similar to those in Fig. 5 although the peaks seem to be rather sharper. In the extreme case where the size limit approaches or passes the modal length, only the right hand, descending, limb of the curve is evident. This condition is rare in waters which are commonly fished, but two examples are shown in Fig. 7. In both cases the curves suggest that the size limits then in force coincided closely with the modal length. Confirmation of this is available for the Maitai since the size limit on this river was experimentally reduced to 10 inches prior to the 1952–53 season and a number of anglers kept diaries of their fishing there in 1952–53 and 1953–54. The size distribution of the 314 fish recorded in these diaries is also shown in Fig. 7, and the mode of this curve is evidently at about 12 inches, which was the original size limit. The inclusion of about 32 per cent of fish which were below the original limiting size is the cause of the decrease in the peak percentages of the curve.

The characteristic shape of the size distribution of fish caught by anglers contrasts strongly with the continually decreasing distributions which must occur in natural populations of fish. The difference is caused by changes with size in the proportion of the fish population which anglers catch. The ascending left-hand

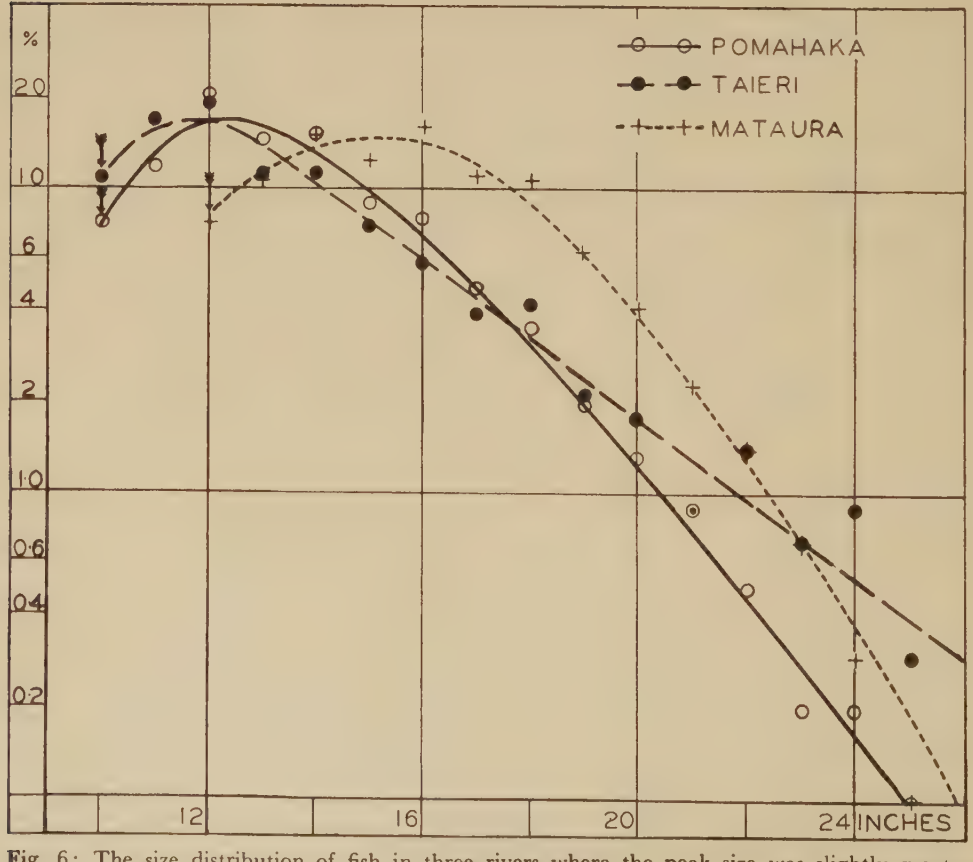


Fig. 6: The size distribution of fish in three rivers where the peak size was slightly greater than the limit.

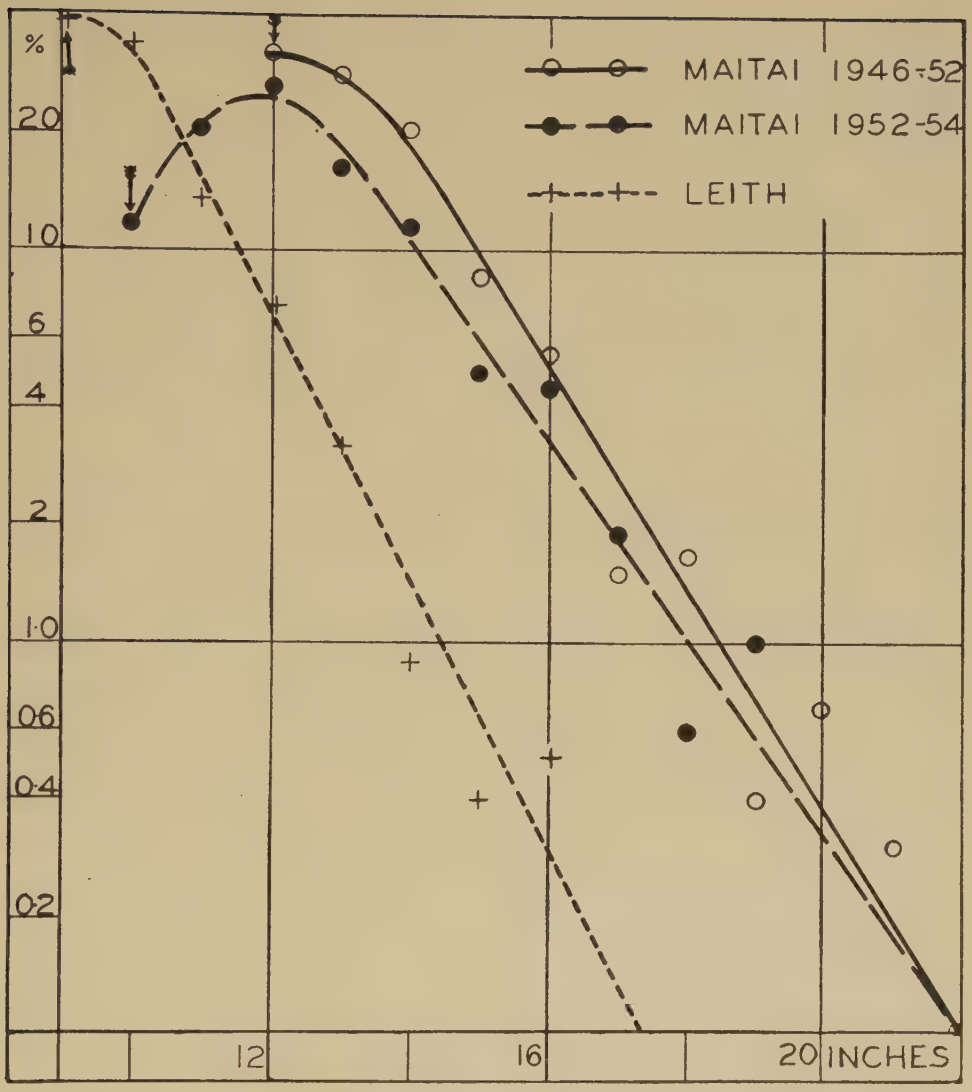


Fig. 7: The size distribution in two rivers where the peak size was about equal to the original limit. For the second period on the Maitai the limit was reduced and was distinctly below the peak size.

limb of the catch curve must be due to a progressive increase with size in the proportion caught. The location of the peak and the slope of the descending right-hand limb is less easy to interpret. In dealing with fish caught in seines and similar nets curves of this type are usually ascribed to fish being equally and completely catchable above a certain critical size, so that the descending limb reveals the structure of the corresponding part of the actual population (Ricker, 1949). Where fish are caught by angling, as in the present instance, this assumption may not hold. It is commonly believed that there is competition among trout for good lies and that the largest fish generally occupy the best positions. This could lead to a progressive increase throughout life in the probability of a fish being caught by an angler. Such a continuous increase would give rise to size distribution curves of the type shown provided that the exponential rate of increase of catchability with size diminished either abruptly or gradually. In a curve arising in this way the right-hand descending limb of the catch size distribution would not parallel that for the natural population but would be less steep.

In most of the curves in Figs. 5, 6, and 7, the slopes of the right-hand limb are rather similar. This slope can be conveniently expressed as the ratio between the proportion of fish of a given size and the proportion of those one inch shorter. The majority of values fall in the range 0·35 to 0·6. A rather higher value occurs in the Taieri where it reaches 0·76. A still more extreme case is found in the Clutha where the right-hand limb is convex rather than straight, the upper part is very much flattened, having a slope of about 0·92. Both the Taieri and the Clutha are large rivers with long and rather diverse courses, and it seems not unlikely that the wide spread of the size-distribution curves may arise from the combination of fish caught in various parts of the river where the populations have different composition. Unfortunately no data are available as to the places of capture of fish taken in either of these rivers, and this hypothesis cannot be tested directly. The effect can, however, be examined for another river in an adjacent district. Fig. 8 shows the size distribution of 2,236 fish recorded from the Oreti River in Southland. The combined curve has a fairly flat right-hand limb with a slope of about 0·7. Analysis shows that in the highest and lowest reaches of this river the size of fish is much greater than it is in the middle reaches, and the size distribution of fish taken in each of these areas is also plotted in Fig. 8. In both the lower and middle reaches, which gave the largest samples, the right-hand limbs are much steeper, being well within the usual range. Only in the upper reaches, where the sample of fish was small (165), was the slope constant as high as in the combined group. It appears therefore that much of the abnormal spread of the original sample was due to the combination of fish from diverse populations.

Detailed study of the records usually shows more or less irregular variation from season to season in the mean length. This variation arises largely from random effects, but it may also be contributed to by changes in the state of the stock, and possibly by differences in the places fished and methods used. Since the size distribution does not usually conform to the normal or any other conventional type, and shows varying degrees of truncation, an accurate measure of the expected random variation of the mean cannot be easily computed from the distributions themselves. Another approach to the problem becomes possible where data are available for the same water from more than one source. The best series of this kind is that from the Mataura river, for which data are available from four sources. These results are summarised in Table 10. For the four central years of the period data can be

obtained from all four sources, and the lower part of the table gives an analysis of variance for this block. The value of *F* for sources is only slightly less than that for 1 per cent probability and indicates that there are consistent differences in the lengths obtained from different sources. Most of this difference probably arises from the consistently low values obtained from Southland rangers' reports. If these records are eliminated analysis of the remaining block gives a value for *F* between sources which falls well short of the 5 per cent probability level. Between years *F*, although considerably greater than 1, does not reach the 5 per cent level, so that the hypothesis that there is no difference in the state of the population between years cannot be rejected. If this hypothesis is accepted the sums of the squares for years and discrepance may be pooled, giving a new mean square of 0·312. This gives an estimate of the standard deviation of 0·559 inches, and variation of up to twice this amount from the overall mean by an individual sample could be accepted by the usual standards as being due to chance effects. Even if the differences between years are assumed to be significant and the original value of the dis-

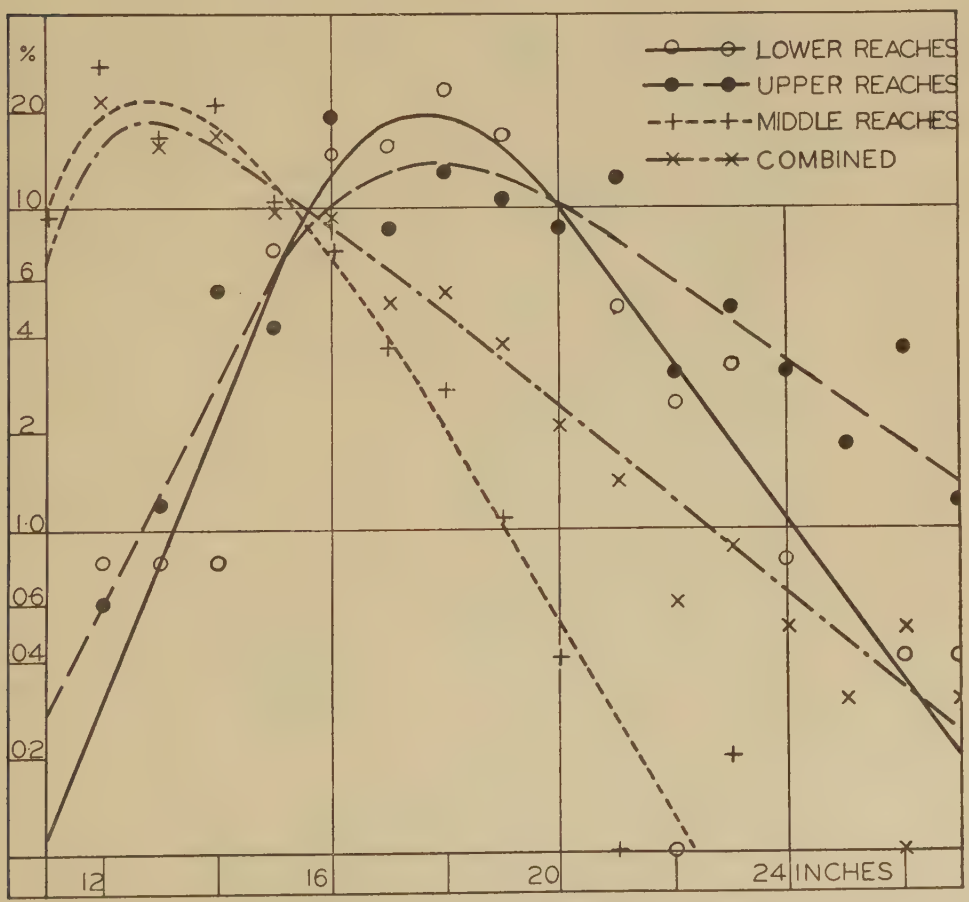


Fig. 8: Size distribution of trout caught in the upper, middle, and lower reaches of the Oreti, and in the whole river.

Table 10. The Mean Length of Fish Taken in the Mataura in Six Different Seasons, and Drawn From Four Different Sources of Data. The Analysis of the Variance of the Mean Lengths

Source	1946–47		1947–48		1948–49		1949–50		1950–51		1951–52		Total	
	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)
Otago diaries	162	16·26	720	16·53	442	16·30	1,135	16·28	1,559	15·88	911	15·82	4,929	16·10
Otago competitions	126	17·47	280	16·57	317	15·93	245	16·67	223	15·82	..	..	1,191	16·38
Southland diaries	..	..	1,242	16·63	824	15·59	536	14·90	526	15·74	692	14·68	3,820	15·68
Southland rangers	..	..	308	15·34	226	15·34	598	14·53	597	15·18	..	..	1,729	15·00
	288	16·79	2,550	16·44	1,809	15·79	2,514	15·61	2,905	15·71	1,603	15·33	11,669	15·83

ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square	*F.*
Source	3	1·198	6·58*
Year	3	0·372	2·04
Discrepance	9	0·181	..

Table 11. The Distribution of Average Length in Each District for the Waters Included in Appendix 1

	Mean Length in Inches												
	10–10·9	11–11·9	12–12·9	13–13·9	14–14·9	15–15·9	16–16·9	17–17·9	18–18·9	19–19·9	20–20·9	21–21·9	22–22·9
Ashburton	..	..	..	..	..	1	2	..	..	..	..	..	..
Auckland	..	..	..	..	1	2	3	3	2	1	1	..	..
East Coast	..	..	..	..	..	..	..	..	1	..	..	..	..
Hawke's Bay	..	..	..	..	1	1	3	..	1	..	..	..	..
Marlborough	..	..	..	..	..	..	..	..	..	1	..	..	..
Nelson	..	..	..	2	1	2	1	2	1	3	1	3	..
North Canterbury	..	..	..	2	..	2	2	..	2	2	..	1	..
Otago	1	1	3	8	3	6	2	..	2	..	..	..	..
South Canterbury	..	2	1	1	2	..	..	..	..	..	..	1	..
Southland	..	..	..	2	4	5	1	1	..	..	..	1	..
Taranaki-Hawera	..	..	..	..	..	2	..	2	2	..	..	..	..
Waimarino	..	1	..	..	1	2	..	1	1	..	..	..	..
Waitaki	..	..	..	..	1	..	..	..	..	..	..	..	..
Wellington	..	..	..	1	2	3	3	..	..	1	..	..	..
West Coast	..	..	..	..	..	..	1	3	..	..	..	..	1
Westland	..	..	..	..	..	..	..	1	..	..	..	..	..
Otago-Southland	..	..	..	..	..	1	..	..	..	..	..	..	..
Ashburton - North Canterbury	..	..	..	..	..	..	..	..	..	1	..	..	..
Auckland-Waimarino	..	..	..	..	..	1	..	..	..	..	..	..	..
South-east	1	3	4	11	10	12	3	1	2	..	..	2	..
Others	..	1	..	5	6	16	15	12	10	9	2	4	1
Total	1	4	4	16	16	28	18	13	12	9	2	6	1

crepance is used, the resulting estimate of the standard deviation, 0·425 inches, does not differ greatly from that previously obtained. It appears therefore that, at least in the Mataura data, annual variation from the overall mean of up to about one inch can be accepted as being due to chance effects.

An alternative approach to the problem can be made by analysing the size distributions themselves. If they conformed to any standard mathematical form a precise estimate of the random variation of the mean would be possible. Since the shape of the curve may vary considerably between different waters, and since in addition the size limit frequently imposes some degree of truncation, no precise and simple solution is practicable. Fig. 5 suggests that in the Mataura, which seems to be typical of a number of waters, the curve is fairly symmetrical until the point of truncation is reached. An estimate of the variance of the entire curve can therefore be made by calculating it as though the lower limb were a mirror image of the upper one. This has been done for a single sample composed of all data from the Mataura and has given an estimate of variance of 7·98. For samples of 600, which is the approximate mean sample size in Table 10, this gives an estimate of the standard error of the mean of 0·115. On this basis variation of the mean of a single sample from the overall mean should be regarded as being due to random effects only if it is less than about 0·23 inches. This figure is so much smaller than that obtained earlier that it suggests that a great part of the difference between mean sizes recorded in different years is due to random changes, not in the fish population, but in factors which affect the characteristics of the sample. Such factors would include the characteristics of the anglers providing records, the methods used, the particular places fished, and weather and water conditions.

In the preceding section it was pointed out that, in a group of districts in the south-eastern part of the South Island, the usual rate of catch was higher than in the rest of the country. Table 11 summarises the distribution of mean length in the various districts and shows that this area is also characterised by a relatively low average size. Since this observation suggests some correlation between rate of catch and the usual size of fish in the population exposed to angling, a more detailed examination of the relationship is desirable. The mean length has therefore been plotted against the rate of catch for all South Island waters in Fig. 9. The result shows that the rate of catch tends to decrease as the mean size increases. This effect must be accentuated by differences in the size limits imposed in different districts. For a given fish population, increasing the size limit will raise the average length of fish caught while it will reduce the rate of catch. Lowering the size limit will have the reverse effect. The existence of different size limits in different waters will therefore tend to cause the points to be spread out in somewhat the way that they are in the figure. The figure also shows that there is a tendency for the waters in the lower right section to have lower size limits than those in the upper left section. To check how far the pattern is due to the variation in size limits and how far it merely reflects the adjustment of size limits in accordance with the characteristics of the fish population the figures for the various waters have been recalculated for a standard size limit. This can only be done by determining what the effect would have been on the results actually recorded if a higher size limit had been in force and the highest size limit commonly employed in the South Island (12 inches) has been used. In a few high-country lakes size limits of more than 12 inches have been in force, but in these small fish are relatively scarce and the original figures have therefore been used. Fig. 10 shows the distribution obtained when the size limit

is standardised. The figure shows that the tendency towards local differences in trout catches is not a result of the differences in size limits. In the figure the crosses represent the extreme southern districts, the white symbols the central and eastern districts, and the black symbols the northern and western districts. There is an obvious tendency for the three types to be grouped in that order as the figure is traversed from lower right to upper left. The inverse correlation between size and rate of catch is also still evident when the effect of the size limit has been eliminated. It is particularly shown by the sloping upper edge of the area occupied by the points, although there has been some filling in of the central area to form a triangle.

Superimposed on both figures is a series of lines showing approximately the combinations of length and rate of catch which will give constant weights of fish per hour's fishing. These lines have been computed on the basis that the mean weight of the fish caught in any water is that of a fish having the given mean length and a condition factor of 120 on the cm.-gm. scale or 43·3 on the Corbett scale. Since the weight of a fish increases approximately as the cube of the length, computation of a figure for the condition factor from the mean weight and mean length of a sample of fish gives a value which is in excess of the real average condition factor. This excess is usually between 5 per cent and 10 per cent, so that the figure used in computing the curves in Fig. 10 corresponds to a true average value of about 112 cm.-gm. scale or 40 Corbett. This is believed to be a reasonably representative value under New Zealand conditions and sufficiently accurate for present purposes.

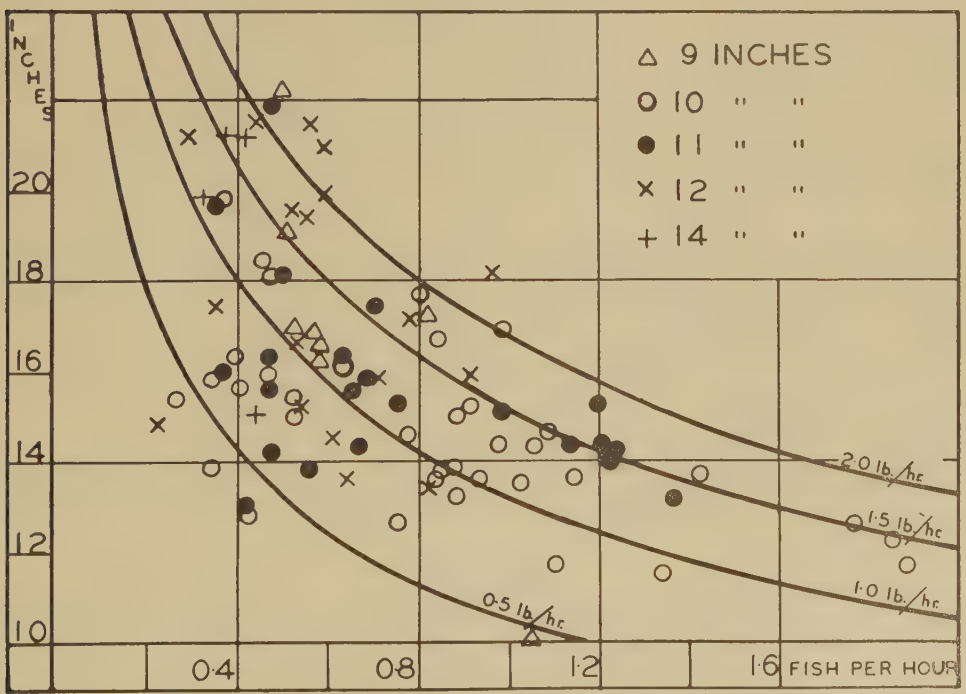


Fig. 9: The average length plotted against number of fish per hour for all South Island waters; the various symbols distinguish the different size limits in force. The curved lines indicate combinations of size and rate giving the same weight of catch per hour.

In Figs. 9 and 10 the points tend to lie along a curve of the same form as the lines of equal weight of catch per hour, indicating that the weight of fish caught by an angler tends to be independent of the size of the individual fish. The original data can therefore be transformed in a way which will give a linear relationship suitable for a test of correlation. Since the weight of a fish is approximately proportional to the cube of its length, and it is assumed that the weight of the catch per hour tends to be constant, the appropriate transformation is to the reciprocal of the cube of the length. The value of the correlation coefficient, *r*, between the length data transformed in this way and the catch per hour is about 0·6, which is very much greater than that for the 1 per cent level of significance (0·27).

The diagram shows that the majority of waters give rates of catch of between 1·0 and 2·0 lbs of fish per hour whatever the usual size of fish caught in them, but that there is a significant group of waters in which a combination of low average size and low rate gives a weight per hour of 0·4 to 1·0 lb.

In order to examine the geographical distribution of the various types of trout population, the position of each water has been marked on the map in Fig. 11 by symbols denoting the population type. In the case of the longer rivers the symbol

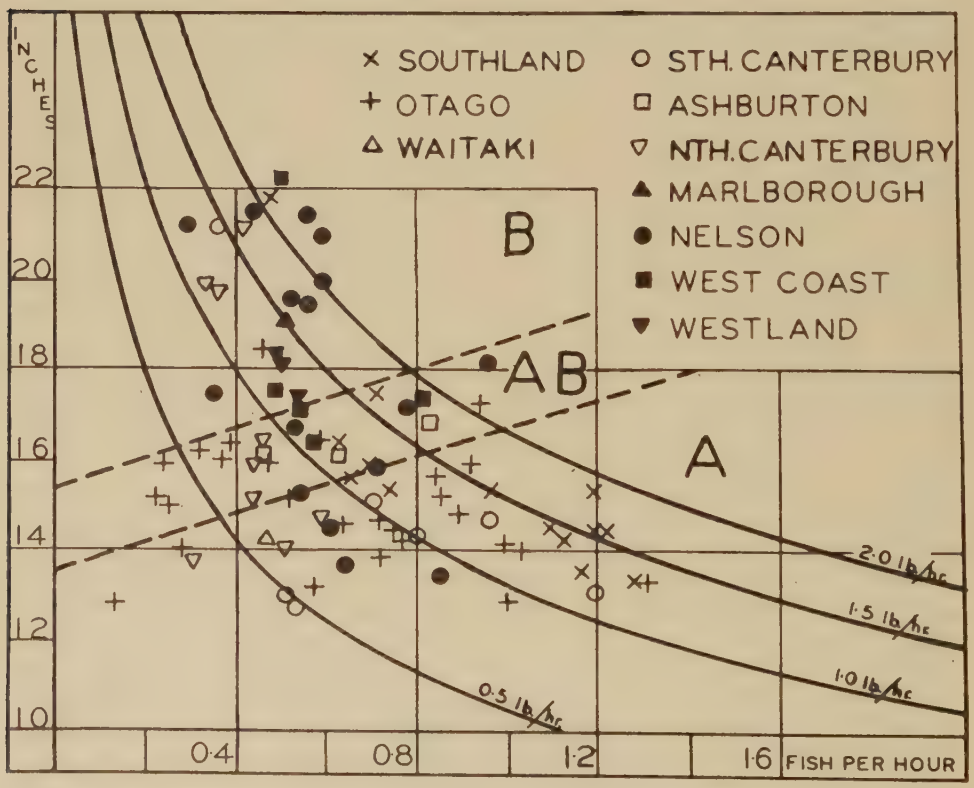


Fig. 10: The average length plotted against number of fish per hour for all South Island waters; the various symbols distinguish acclimatisation districts. The straight broken lines divide the different population types. The points have been adjusted for the effects of a 12-inch size limit.

Fig. 11: The distribution in the South Island of trout population types classified on the basis of Fig. 10. The shaded area represents steep country, and the broken line divides Area **a** to the south-east, from Area **b** to the north-west.

has been placed approximately at the believed "centre of gravity" of angling on that river. For Fig. 11 classification has been based on the inverse relation between mean length and rate of catch. For this purpose two arbitrary lines have been used to divide the field of distribution into three zones. These lines are shown broken in Fig. 10. The waters characterised by numerous small fish and occurring below and to the right of the lines are known as type A. Those with larger and less numerous fish and occurring above and to the left are type B. The intermediate waters lying between the lines form type AB. In Fig. 11, type A waters are shown by white circles, type B by black circles, and type AB by divided circles. The figure shows clearly the grouping of black circles to the north and west and the white to the south and east. On the map, a line extending from Cape Campbell in the north to the western end of Te Waewae Bay in the south has been used to divide the island into two regions. The area to the south-east of the line, characterised by type A waters, will be referred to as Area **a**, that to the north-east will be similarly referred to as Area **b**.

Fig. 11 shows that in each area the aberrant waters form one small geographical group. Of the type B waters in Area **a**, three are Lake Ellesmere, its tributary the Selwyn River, and the nearby Rakaia River. In Area **b** the type A waters are three small streams close to Nelson.

Since geographical position alone would not account for the different types of trout population found in the two halves of the South Island, it is of interest to seek other factors which are similarly distributed. In Fig. 11 the area shown shaded is that marked in the map given by Taylor (1948) as occupied by "steep slopes". It is obvious that there is relatively little steep country in Area **a**, whereas it predominates in Area **b**. Most of the points marked in Area **b** lie actually in steeply sloping country or close to the edge of it in fairly small areas of gentler slope. On the other hand, in Area **a** most of the waters for which data are available lie in large areas of flat or gently rolling land, in Southland, southern Otago, and Canterbury.

Further information can be obtained if the waters are subdivided according to their physical type. For this purpose, four categories have been selected. These are: rivers having a drainage area of more than 300 square miles; streams which are independent systems having a drainage area of less than 300 square miles; tributaries of other streams or rivers, and lakes including artificial reservoirs. Table 12 shows for each of these physical types, in both areas, the number of waters having populations of each type. The table shows that the characteristic difference between the two areas is most pronounced in the rivers and tributaries. In Area **a** 26 out of 39 rivers and tributaries are of type A, while in Area **b** 14 out of 19 are of type B and there are none of type A. Streams in both areas seem to be characterised by type A populations although the samples are few. Populations of the few lakes for which data are available are also in accord with the areas in which they occur. There are, however, certain physical differences between the waters themselves, in that many of the lakes in Area **a** are actually artificial reservoirs, while all those in Area **b** are natural. The results for some of these lakes are also complicated by the artificial stocking which was done in the period to which the records refer. In several cases quite rapid alterations in the state of the stock have resulted from changes in policy by the bodies concerned with the liberations. It may be noted that most of the lakes in Area **b** drain into rivers

Table 12. The Distribution of Trout Population Types in the Various Types of Waters in the North Island and the Two Areas of the South Island

Region	Water Type	Population Type			Total
		A	*AB*	*B*	
North Island	River	1	6	1	8
	Stream	1	2	6	9
	Tributary	5	12	8	25
	Lake	..	1	1	2
	Total	7	21	16	44
South Island—Area **a**	River	5	7	1	13
	Stream	6	6	..	12
	Tributary	21	4	1	26
	Lake	4	3	2	9
	Total	36	20	4	60
South Island—Area **b**	River	..	1	7	8
	Stream	3	1	..	4
	Tributary	..	4	7	11
	Lake	..	3	3	6
	Total	3	9	17	29

which flow through Area **a** and which have provided data for this area from their lower courses. If data from a greater number of waters were available, it would be possible to construct a more detailed map which would show more clearly the nature of the correlations between the type of trout population and physical and geological features. The data at present available show, however, that, in general, rivers and lakes in steep country of high relief contain trout stocks which yield to the angler fish fewer in number but of greater average size than those taken from waters in country of lower relief.

In Fig. 11, only one point is shown for each river except the Buller, which is fished in its upper reaches by anglers of the Nelson district and in its lower reaches by anglers of the West Coast district. As stated earlier, the point for each river has been placed as nearly as possible at the centre of gravity of angling, and in most cases this is somewhere in the lower reaches. It is well known that in many large rivers the trout stocks have different characteristics in different parts of the course. In many cases three zones may be distinguished: a short tidal zone at and just above the mouth of the river, where the fish are often large; a middle zone flowing through plains or large alluvial valleys, often the site of most of the angling, and containing fish of smaller size; and an upper zone where the river lies in narrow valleys between high hills, and where fish are often relatively large. Nearly all the points plotted for major rivers on Fig. 11 refer primarily to the middle zone and show that there is a tendency, even in this zone, for the distinction between the trout populations in the two parts of the South Island to be apparent.

Only one water has been found in which adequate quantities of data are available from all three zones. This is the Oreti River in Southland. The river has been divided into three zones: the lower zone consists of about six miles of tidal water

and extends up to Ferry Bridge; the middle zone lies mostly in alluvial plain and extends for about 70 miles to Mossburn; the upper zone lies above Mossburn and extends for many miles back into the hills, although most of the fishing is probably done in the lowest six miles of this. Table 13 shows the rate of catch and average size of fish taken in these three zones. The mean length in the middle zone is very much less than in either of the others, and the population of this zone belongs to type A while those of the lower and upper zones belong to type B. A similar though smaller difference also exists in the Buller River between the upper zone fished by Nelson anglers and the lower zone fished by West Coast anglers. The less pronounced difference here may be correlated with the fact that throughout its course the Buller lies in or very close to steeply sloping country.

Table 13. The Mean Length and Rate of Catch for Trout Caught in Three Zones for the Oreti and Two Zones for the Buller

Zone	Number of Hours	Number of Fish Measured	Fish Per Hour	Mean Length (Inches)
Oreti—				
Lower	284	248	0·77	18·09
Middle	813	1,823	0·85	13·58
Upper	186	165	0·90	18·81
Buller—				
Lower	139	77	0·55	17·04
Upper	2,275	1,189	0·56	19·41

In the foregoing discussion, waters have been classified according to the relation between the average size of fish and the rate of catch, but if they are classified on the basis of the average weight of fish caught in an hour's fishing, a very different pattern is found. Fig. 12 shows that in most parts of the South Island the average catch per hour usually exceeds 1 lb. in weight. Nearly all the waters giving lower rates are concentrated in an area in south Otago and eastern Southland, although there are two small groups near to Christchurch and Nelson. Comparison with a geological map of the South Island shows that most of the waters in the main group have their source in the broad belt of metamorphic rock (schist) which extends across this part of the country. More specific studies are, however, needed to show whether there is in fact any correlation between rocks of this type and relatively inferior trout populations.

Examination of the South Island data has shown definite patterns in the distribution of certain features of the trout stocks. In the North Island no such clear patterns are apparent. In the whole island, the records include 7 type A waters, 20 type AB waters, and 16 type B waters, and these are distributed in a more or less irregular manner over the whole island. The position is complicated by the fact that in the North Island two species of trout occur commonly, while in the South Island nearly all the waters examined contain only brown trout. As will be shown later, the southern half of the North Island is dominated by brown trout, but north of a line extending roughly from southern Hawke's Bay to Taranaki rainbow trout are dominant in most areas. Reference to the map previously mentioned (Taylor, 1948) shows that in the brown-trout area the distribution of steep country is much more irregular than is the case in the South Island. This may have some correlation with the irregular distribution of the trout population

Fig. 12: The distribution in the South Island of waters giving rates of catch greater and less than 1 lb. per hour. The shaded area represents schist.

Table 14. The Distribution of the Percentage of Undersized Fish in Anglers' Catches in the Waters of Each District. In the Hawke's Bay and Waimarino districts different size limits are in force in the same waters for different species of fish.

District	Size Limit (Inches)	Percentage Undersized						
		0–9·9	10·0–19·9	20·0–29·9	30·0–39·9	40·0–49·9	50·0–59·9	60·0–69·9
Ashburton	10	..	1	1	..	..	..	..
	14	1	..	..	..	..	..	..
Auckland	12	1	1	3	2	4	1	1
East Coast	14	..	..	1	..	..	..	..
Hawke's Bay	10, 12	..	4	..	1	1	..	..
Marlborough	9	1	..	..	..	..	..	..
Nelson	12	4	5	3	..	2	2	..
North Canterbury	11	1	2	2	1	1	1	..
	14	1	1	..	..	1	..	..
Otago	9	..	..	..	..	1	1	..
	10	4	4	6	8	2	..	..
South Canterbury	10	..	1	1	2	2	..	..
	14	1	..	..	..	..	..	..
Southland	11	2	5	2	4	..	1	..
Taranaki-Hawera	11	..	1	1	2	..	..	..
	12	..	..	..	1	..	1	..
Waimarino	9, 10, 12	1	1	3	..	..	1	..
Waitaki	11	..	..	..	..	1	..	..
Wellington	11	..	4	4	1	..	1	..
West Coast	9	3	2	..	..	..	..	..
Westland	9	1	..	..	..	..	..	..
Ashburton - North Canterbury	11	1	..	..	..	..	..	..
Auckland-Waimarino	12	..	..	..	..	1	..	..
Otago-Southland	12	..	..	1	..	..	..	..

types. In most of the rainbow-trout area, low relief country predominates, although about half of these populations are of type B and there are no type A populations. These results rather suggest that the physical features which cause the nature of the terrain to affect the state of the brown-trout population operate in a different way with rainbow trout. The distribution of weight of fish caught per hour's fishing is also irregular in the North Island.

3. PROPORTION OF UNDERSIZED FISH

SUMMARY

The proportion of undersized fish in anglers' catches varies greatly, both between districts and between waters in the same district. It is particularly high in the south-east of the South Island.

There is a strong positive correlation between the size limit and the mean length, probably due both to the direct effect of the limit in eliminating the smallest fish from the catch and to a tendency to adjust the limit to the usual size of fish in the stock. There is also a negative correlation between the mean length and the proportion undersized because the larger the usual size of fish is in relation to the limit the fewer will be the undersized fish. In waters with fish of any given average size there is a positive correlation between size limit and proportion undersized, but in the combined data this is offset by the negative correlation between length and proportion undersized, and the original correlation disappears.

The proportion of undersized fish varies according to the method of fishing, but the type of variations differ from water to water. Waters most suitable for fly fishing tend to give diminishing proportions undersized for fly, minnow, and worm respectively, but the reverse tendency occurs where minnows and worm are the favourite methods. There is usually no significant difference between dry and wet fly.

The proportion of undersized fish in the catches of anglers on any given water will depend basically on the size distribution of the population and on the value of the size limit. It has already been shown that the size distribution of trout stocks in New Zealand varies greatly amongst different waters. Different size limits are also imposed in different acclimatisation districts, sometimes more than one in a single district. Size limits have generally been imposed as the result of a belief that they are necessary for the proper protection of the trout population, and the value selected has been one which would normally lead to the return of a fairly small proportion of the fish taken. In no case is the value of the size limit based on a thorough scientific study of the requirements of the particular trout stock. In these circumstances a considerable diversity in proportion of undersized fish recorded from different waters is to be expected. This is clearly shown in Table 14. In nearly all districts there is considerable variation in the proportion of undersized fish taken in different waters, usually from very small numbers up to about half the total catch. Some variation between districts is also evident; the Auckland district is characterised by high percentages of undersized fish, while at the other

Table 15. The Number of Fish and Percentage Undersized Caught by the Four Principal Methods in Various Waters

Water	Dry Fly		Wet Fly		Minnow		Worm	
	Number of Fish	Percentage Undersized	Number of Fish	Percentage Undersized	Number of Fish	Percentage Undersized	Number of Fish	Percentage Undersized
Mataura	.. 1,907	9·0	348	39·4	1,215	32·3	671	18·9
Pomahaka ..	.. 881	38·1	1,593	40·4	1,010	28·7	516	24·0
Clutha	.. 27	0	45	13·3	485	24·7	1,119	30·6
Taieri	.. 54	27·8	14	28·6	355	29·3	256	63·3
Waipahi	.. 630	41·7	406	44·6	52	23·1	149	10·1
Motueka	.. 1,467	15·8	290	16·2	539	17·6	..	..

extreme small percentages are predominant in such districts as Hawke's Bay and the West Coast. The regional distribution of the size of trout in the South Island, which has already been discussed, also shows its effects in the proportion of undersized fish in the catches. The districts of the south-eastern area, Southland, Otago, Waitaki, and South Canterbury, in which the average size of takable fish tends to be small, show high percentages of undersized fish. In these districts 31 out of 50 waters (62 per cent) yield more than 20 per cent of undersized fish, while in the north-western area only 15 out of 39 waters (38 per cent) exceed this figure. In the North Island the diversity in the percentage undersized is greater than in either region of the South Island.

A statistical analysis of the relation between the percentage of undersized fish in the catches, the mean length, and the size limit is presented in Appendix 2(a). This shows that the mean length tends to vary directly with the size limit, both because of a general tendency to adjust local size limits to the usual size of fish caught and because, for similar fish populations, differences in the size limit will produce corresponding differences in the mean size of the fish which can legally be caught. The proportion of undersized fish tends to vary, however, inversely to the mean length because a given size limit will remove a diminishing proportion of the catch as the average size of the fish population increases. These opposing effects tend to cancel each other out, so that the proportion of undersized fish actually returned by anglers shows no relation to the size limits in force.

The data on which this study is based are derived from angling by a variety of different methods, and it is therefore necessary to consider whether results based on comparisons between different waters may not be complicated by the use of different methods on them. To investigate this point, Table 15 has been drawn up showing the percentage of undersized fish in the catches obtained by each of the four principal methods on the six waters for which most data were available. This table is based on the diaries for the 1950–51 and 1951–52 seasons since only these were analysed by methods which enabled the results obtained by different angling methods to be conveniently distinguished. This table shows clearly that there are no consistent differences between methods which appear for all waters. Between dry fly and wet fly for instance, the figures are very similar for all waters except the Mataura, and in each case application of the chi-square test shows that the differences are not statistically significant. On the other hand, the percentage of undersized fish taken by wet-fly fishing in the Mataura is much greater than that taken by dry-fly fishing and the difference is highly significant statistically. To test further the reality of this difference the results for each method have been tested for homogeneity. In each case the data are derived from four sources since they refer to two seasons, 1950–51 and 1951–52, and have been contributed by anglers from two districts, Otago and Southland. Application of a chi-square test shows that for each method the variation between the four groups is much below the significant level, and that the results for each method may be regarded as homogeneous. In the Mataura, therefore, there is a real and substantial difference between the proportion of undersized fish taken by dry-fly fishing and wet-fly fishing, but in the other waters examined there is no such difference.

When comparison is made between wet-fly and minnow fishing, different results are obtained. In three waters, the Mataura, Pomahaka, and Waipahi, the proportion of undersized is greater in wet-fly fishing, and in each water the difference is significant at the I per cent level. In the other three waters, the Clutha, Taieri,

and Motueka, the difference is not significant and in the first two the fly-fishing samples are very small. In each case, however, the percentage is slightly higher in minnow fishing.

A rather similar pattern is found when comparison is made between minnow and worm fishing. In the waters of the first group, the Mataura, Pomahaka, and Waipahi, the percentage undersized is higher for minnow fishing than for worm fishing to an extent which varies from just short of 5 per cent significance on the Pomahaka to well over 1 per cent significance on the Mataura. In two waters of the other group, the Clutha and Taieri, the percentage undersized is significantly higher for worm fishing than for minnow fishing. Worm fishing was not employed on the Motueka, and no comparison is therefore possible for this water.

Thus, in this small sample of waters, nearly all situated in the extreme south-east of the South Island, two main groups may be distinguished. The first group, the Mataura, Pomahaka, and Waipahi, shows a progressive and significant reduction in the proportion of undersized fish as fly, minnow, and worm fishing are considered. These waters lie close together in similar terrain and have the further common feature that fly fishing is the most important method used there. Of the fish recorded in the present analysis the respective percentages caught on fly were 54·5, 61·8, and 83·6. In the Mataura, the dry fly gave a remarkably low proportion of undersized fish, but in the other two waters there was no significant difference between wet and dry fly.

The second group includes the Clutha and Taieri rivers, which lie adjacent to each other and slightly to the north of the first group, although the Pomahaka drains into the Clutha. In these, the percentage undersized shows a reversed relation to method, being highest in worm fishing and lowest in fly fishing, although the difference between fly and minnow is not significant. There is no difference between dry and wet fly. Unlike the waters of the first group, those of the second are fished mainly with minnow and worm, the percentages of fish taken on fly being only 4·3 and 10·0 respectively.

The Motueka, which lies at the opposite extremity of the South Island, shows some similarity to the second group in that the percentage undersized is no higher for fly than for minnow. The absence of worm fishing prevents a full comparison.

This analysis of the results for the few waters which gave adequate samples of data shows clearly that there is no standard relationship applicable to all waters between method and percentage undersized. It suggests that in waters of certain types there are characteristic relationships between the percentage of undersized fish taken by different methods, and that these relationships are similar for waters of the same type and different for waters of different type.

4. DISTRIBUTION OF SPECIES

SUMMARY

About twenty species of fish have been introduced into New Zealand but only three are of any wide importance to anglers. These are brown trout (*Salmo trutta*), rainbow trout (*S. gairdnerii*) and quinnat salmon (*Oncorhynchus tschawytcha*). The last is mainly restricted to the east coast of the South Island, but the others are

more widespread. The relative distribution of brown and rainbow trout is shown in Appendix 1 and summarized in Table 16. In the South Island brown trout are dominant except in some high-country lakes and the associated rivers. In these, various proportions of the two species of trout are found and, in some, "land-locked" stocks of quinnat salmon occur. In the North Island the distribution pattern is more complex (see Fig. 13). Trout are virtually absent from the northern extremities, the east coast, and small areas round Wanganui and north of New Plymouth. In the north, high temperatures probably prevent the establishment of trout and in the other areas the softness of the surface rocks prevents the formation of suitable spawning gravels in the stream beds. In the rest of the North Island rainbow trout predominate to the north of a line from southern Hawke's Bay to north Taranaki and brown trout to the south of it, while fairly evenly balanced stocks occur near the line itself. It appears that ecological rather than historical factors are responsible for the present distribution although the original liberations were largely in accordance with it. This is indicated by the dominance in mixed stocks of the appropriate species in each area and by the fact that at some time almost all waters have received both species. Where both species occur in the same water there is little difference between them in the normal size of fish caught by anglers, although brown trout tend to be slightly larger.

There is little evidence as to the nature of the ecological factors responsible for the distribution pattern. In particular, the boundary between the two main North Island areas does not correspond with any climatic line which has been identified.

About twenty species of fresh-water fish have been introduced into New Zealand at various times, but only about half of them have become established. Of these, three, brown trout (*Salmo trutta*), rainbow trout (*S. gairdnerii*) and quinnat salmon (*Oncorhynchus tschawytcha*) are common over large areas and support the main fresh-water fisheries. Two others, Atlantic salmon, (*S. salar*), and American brook trout (*Salvelinus fontinalis*), are of interest to anglers in small areas, while two more, sockeye salmon (*O. nerka*) and American lake trout (*Cristivomer namaycush*) may be occasionally taken in one or more waters. In addition to these salmonids, a few other species are established in some waters, but the perch (*Perca fluviatilis*) is the only one which is at all widely distributed, and even this is of little interest to New Zealand anglers and is not often deliberately fished for.

Of the three species that provide the great bulk of New Zealand angling, the quinnat salmon, which is largely confined to the east coast of the South Island, is to a great extent the subject of a special fishery using distinct methods and operating at the mouths and in the lower and middle reaches of the major rivers. The two species of trout are, between them, distributed over a much larger area and are found in a greater variety of waters. They are also fished for by more varied methods. As a result of this situation, on any given day an angler is likely to be fishing either for salmon or for trout, but not for both. There is also some tendency for individual anglers to specialise in either salmon or trout, and a better overall response to the diary scheme was obtained from trout anglers.

Table 16. The Distribution of Species for Each District Among the Waters Included in Appendix 1

Percentage Brown Percentage Rainbow	100 0	90–99 1–10	80–90 10–20	70–80 20–30	60–70 30–40	50–60 40–50	40–50 50–60	30–40 60–70	20–30 70–80	10–20 80–90	1–10 90–99	0 100	No data, Other Fish
Ashburton	2	..	..	..	..	..	..	..	..	..	..	..	1
Auckland	..	..	..	..	..	..	1	..	1	..	5	6	..
East Coast	..	..	..	..	..	..	..	..	..	..	..	1	..
Hawke's Bay	1	..	..	..	..	..	..	..	..	..	1	..	4
Marlborough	1	..	..	..	..	..	..	..	..	..	..	..	..
Nelson	16	..	..	..	..	..	..	..	..	..	..	..	..
North Canterbury	6	2	1	..	..	..	..	..	..	..	..	1	1
Otago	26	..	..	..	..	..	..	..	..	..	..	..	..
South Canterbury	6	..	..	..	..	..	..	..	..	..	1	..	..
Southland	10	2	1	1	..	..	..	..	..	..	..	..	..
Taranaki-Hawera	3	3	..	..	..	..	..	..	..	..	..	..	..
Waimarino	2	2	..	..	..	..	..	1	1	..	..	..	..
Waitaki	1	..	..	..	..	..	..	..	..	..	..	..	..
Wellington	8	1	..	..	..	..	..	..	..	1	..	..	..
West Coast	5	..	..	..	..	..	..	..	..	..	..	..	..
Westland	1	..	..	..	..	..	..	..	..	..	..	..	..
Otago-Southland	1	..	..	..	..	..	..	..	..	..	..	..	..
Ashburton - North Canterbury	..	1	..	..	..	..	..	..	..	..	..	..	..
Auckland-Waimarino	..	..	..	..	..	1	..	..	..	..	..	..	..
South Island	75	5	2	1	..	..	..	..	..	..	1	1	2
North Island	14	6	..	..	..	1	1	1	2	1	6	7	4

The most useful information on the distribution of the various species which has emerged from the diaries is that concerning the occurrence of brown and rainbow trout, and Appendix 1 therefore shows, for each water, the percentage of each of those species in the catches. These percentages are usually based on about the same number of fish as was measured for that water, although sometimes the number is less because a few anglers failed to record species. In a few waters where both species are known to occur the proportions have been left blank; this has been done where failure to record species has reduced an initially small sample to a level where no reliable estimation of percentage is possible. While the records show with some degree of accuracy the proportion of the two species in anglers' catches, it must be realised that they do not necessarily show the proportions in the fish population. It seems to be now generally accepted both in New Zealand and elsewhere that under most conditions the rainbow trout is more easily caught than the brown trout (Needham, 1938). It is probable, therefore, that in most waters where both species are present the rainbow trout will form a larger proportion of the catch than of the population from which it is taken. The position may in some cases be further complicated by differences in the specific composition of the population in different parts of the same water. While it is known from general observation that such conditions do occur, the diaries have not given sufficient data to permit of detailed analysis in any water where this applies.

Where the capture of species other than brown and rainbow trout has been recorded, this is indicated in the appendix, although the proportion of the other species is not generally shown since the data are usually not adequate in this respect. An exception has been made for those South Island lakes and associated rivers which contain stocks of small "land-locked" salmon of either Atlantic or Pacific forms. In these waters the salmon are more or less similar in size and habits to the trout and are caught by the same methods. Their percentage in the catch is therefore shown in the appendix.

Since the appendix is based entirely on the records provided over a few seasons by a relatively small number of anglers, it does not always provide a record of the occurrence of the scarcer or less important species; they may be present in some waters from which they were not recorded by the diarists. In addition, some waters where one of the two principal species predominates also contain small numbers of the other although they were not recorded. Where the second species formed much less than 1 per cent of the recorded catch it has been omitted.

The distribution of brown and rainbow trout in the waters of the various acclimatisation districts is summarised in Table 16, and several points emerge clearly from it. The first of these is the complete dominance of the brown trout in the South Island, contrasted with the more balanced occurrence of the two species in the North Island. The nature of the distribution within each island will be discussed later. The second point is the well-marked tendency for one or other species to predominate and the scarcity of waters containing a more or less evenly divided population. Of 124 waters, 97 (78 per cent) contain only, or virtually only, one species, while in a further 18 (15 per cent) one species forms over 90 per cent of the catch, leaving only 7 per cent in which more evenly divided populations occur. Further examination discloses a difference between the two species in this respect. Where the brown trout is predominant, its dominance, is very complete, and of 102 waters yielding over 80 per cent brown trout, 89 (87 per cent) contain virtually only this species. On the other hand, populations dominated by rainbow trout more

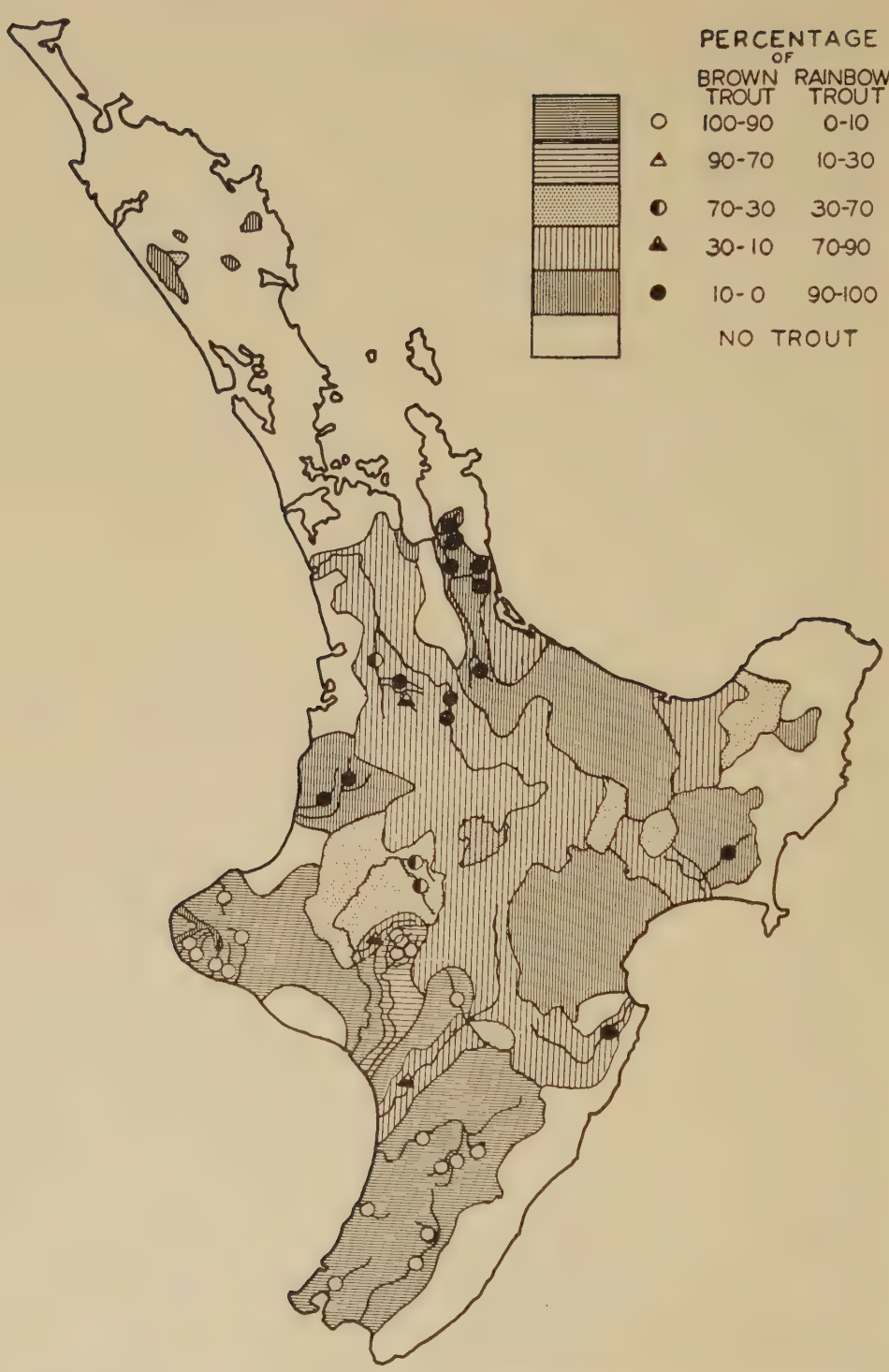


Fig. 13: The distribution in the North Island of populations containing varying proportions of brown and rainbow trout.

often contain a few brown trout as well, and out of the 16 waters containing over 80 per cent rainbow trout exactly half contain at least 1 per cent and usually from 2 per cent to 5 per cent brown trout. This tendency is further confirmed by study of the results from the waters which gave smaller amounts of data and are therefore not shown in the appendix.

In the South Island the occurrence of rainbow trout is closely associated with the high-country lakes. The majority of these lakes have been stocked at various times with both brown and rainbow trout, and a few of them with other species as well. In some, such as Lakes Heron and Coleridge, "land-locked" stocks of quinnat salmon have become established. The stocks of a few lakes are almost entirely maintained by liberations but, in general, natural reproduction plays a major part in the maintenance of the populations. The specific composition of the fish population of any particular lake therefore largely represents the natural balance achieved by the species in that particular environment. This balance may be struck at any point between complete dominance of rainbow trout and complete dominance of brown trout.

In Lake Coleridge the diaries recorded only rainbow trout, but brown trout are also present in small numbers. In Lake Alexandrina, also, the records show a great excess of rainbow trout although both species are present. At the other extreme, Lake Rotoiti contains so few rainbow trout than none were included in the recorded catches despite strenuous efforts to establish this species in the lake. In Lake Heron a more even distribution of the two species of trout seems to occur although the fish population is dominated by "land-locked" quinnat salmon. Information available from other sources concerning lakes that did not yield adequate quantities of diary data confirms the existence of great variation in the specific composition of the fish populations of South Island lakes.

The South Island rivers from which rainbow trout were recorded in the diaries belong almost entirely to river systems containing lakes with populations of this species. The three river systems concerned are the Waiau, which drains Lakes Te Anau and Manapouri, where rainbow are predominant, and the Waimakariri and Rakaia, whose systems include a number of small lakes containing rainbow trout. Except for the Waiau and its upper tributaries such as the Mararoa, and for certain areas in the lower Waimakariri system, the proportion of rainbow trout is very small in these waters. There are also other large South Island rivers such as the Clutha and Ashburton which have lakes containing rainbow trout in their headwaters, but which yield rainbow trout so rarely that none were recorded in the diaries. A single rainbow trout was recorded from the Avon, which is a small stream having no lakes in its system but which enters the sea close to the mouth of the Waimakariri. There are also known to be a few rivers in the South Island, such as the Kaituna and Wakamarina in Marlborough, which contain some rainbow trout, although they are remote from any major population of this species. They are small rivers and provided no diary data. The general position in the South Island is therefore that rainbow trout are rarely found except in waters connected with high-country lakes, and that they then occur in association with brown trout in varying proportions.

In the North Island a very different situation occurs, and the distribution of the two species shows a much clearer geographical pattern. This is illustrated in Fig. 13. This shows the composition of the population in each of the North Island waters included in the Appendix 1, the populations being divided into five categories for

this purpose. Superimposed on these points is a subdivision of the island into areas containing populations of the various types. This subdivision is based on information concerning many other waters which is on file at the Fisheries Laboratory. Although this information is not yet complete, it is believed that the map shown is substantially correct and that further study is unlikely to cause more than minor amendments to the various boundaries.

Where trout are established in the North Island there seems to be a fairly clear division between a southern area where brown trout predominate and a northern area dominated by rainbow trout. The boundary between these areas follows throughout most of its length a line (which is almost as direct as river-system boundaries will allow) between a point on the east coast about 40 miles south of Cape Kidnappers and one on the west coast in north Taranaki near Waitara. The main divergences from this line are found in two major river systems which rise to the north of it and flow southwards into the southern area. These are the Rangitikei system, where rainbow trout predominate throughout except for one tributary, and the Wanganui system, where brown and rainbow trout are in approximately equal numbers in the upper reaches and tributaries, and where trout are scarce in the lower reaches although brown trout are believed to predominate.

In the northern area the whole of the extensive Waikato system contains both species, with the rainbow trout predominating to varying extents. The same applies to the southward-flowing Rangitikei system and to the Tukituki system flowing eastwards into Hawke's Bay. North of this belt of mixed but predominantly rainbow trout stocks, lies an area in much of which practically pure populations of rainbow trout are found. A rather complex situation appears to exist towards the north-east corner of the area but further study is needed to establish with certainty the present nature of trout populations here.

In the southern area pure stocks of brown trout occupy most waters, although in a few, such as the Otaki, rainbow trout are very occasionally caught. In some of the upper Manawatu tributaries, such as the Mangatainoka, a small but persistent proportion of rainbow trout appears in the catches. Within the area enclaves in which rainbow trout is the more abundant species are few and small. In Taranaki they include two streams flowing off Mount Egmont and the headwaters of a few others. In the Wairarapa district there is a pure population of rainbow trout in a small isolated reservoir, and similar stocks are found in a few isolated lakes on the Wellington west coast. These small waters are not marked on the map. It should perhaps be emphasised that in the southern or brown-trout area of the North Island the high-country lakes which are a feature of many South Island river systems and which appear to be often associated there with the occurrence of rainbow trout are completely absent.

In addition to showing the relation between the distribution of brown and rainbow trout, the map also shows the location of the troutless areas. These consist largely of the northern extremities of the island and a strip down the east coast. Trout have probably been liberated from time to time in most of the waters in these areas and their absence must therefore be ascribed to ecological factors. Until more detailed studies are carried out, the nature of these factors is uncertain, but it seems likely that in the northern areas the absence of trout may be due to high temperatures at some seasons. On the east coast, in the Wanganui area on the south-west, and north of New Plymouth, the absence of trout appears to be

correlated with the occurrence of soft sedimentary rocks which do not break down to form, in the river beds, gravels suitable for spawning.

Interpretation of the present distribution of brown and rainbow trout in New Zealand is complicated by the need to consider two entirely different groups of factors, the historical and the ecological. In a land where both species have been introduced from overseas, they can only occur in those waters to which they have been transported. In most cases a species which has been introduced into one part of a river system can be expected to spread to all parts of the system which are ecologically suitable for it. Natural distribution of this kind may, however, be limited by natural barriers. The commonest of such barriers are waterfalls, which may prevent upstream dispersion while allowing downstream movement. The pure population of brown trout in the upper Hautapu river is isolated by a waterfall, but this species also predominates in the lower part of the river, despite the dominance of rainbow trout in the rest of the Rangitikei system. Natural barriers of a more unusual but even more effective nature are formed by zones of hot or chemically polluted water produced by thermal springs. Such barriers isolate some of the tributary subsystems of the upper Wangaehu system, and have enabled populations of differing specific composition to become established in them. Natural barriers of whatever kind are rare in most districts and even where they do occur the same species or combination of species has usually been introduced above and below them.

The brown trout was the first species introduced, being brought into the South Island in 1867. By 1880 it had been liberated in many parts of the South Island and in the provinces of Wellington, Taranaki, and Hawke's Bay in the North Island; a few liberations had also been made in the Auckland Province (Hobbs, 1948). Spakman (1892), writing of brown trout in 1892, records "most of the rivers in the [South] Island being well enough stocked to afford magnificent fishing. . . . In the North Island they have been successfully introduced into most of the rivers as far north as Taranaki on the West Coast and the inland portion of Hawke's Bay on its eastern side." It may be noted that this defines with remarkable exactness the area dominated by brown trout at the present time.

The central part of the North Island was still largely inaccessible during this period, but liberations in the settled region in the north of what is now the rainbow-trout area were largely in the hands of the Auckland Acclimatisation Society. This body began to liberate brown trout on a small scale in 1874, but many of the fish were placed in waters which have never proved satisfactory for trout of any species. In 1883 and 1884, however, this society brought the first rainbow trout to New Zealand, and from about 1890 onwards this species was liberated in the district in rapidly increasing numbers, while very few more liberations of brown trout were made. In the centre of the North Island, Lake Taupo at the head of the Waikato river received its first liberation in 1885. This was of brown trout, and although there is now uncertainty as to its success, it was followed by heavier liberations of this species in 1894 and subsequent years. As a result brown trout became established in the lake in sufficient numbers for some to be caught by anglers. In 1897, however, the first liberations of rainbow trout were made in the tributaries of the lake, and these were followed with others in the years from 1900 onwards. In 1904 rainbow trout first appeared in anglers' catches, and within a few years had completely dominated the brown trout in them. At the present time both species still exist in the lake although the rainbow trout is taken in much greater numbers. The

position in the lake is therefore the same as that occurring in the rest of the Waikato system.

On the East Coast information on the early history of the fish population is difficult to obtain, but there is evidence that the part of northern Hawke's Bay which now contains almost pure rainbow stocks was receiving approximately equal liberations of the two species during the 1900's.

Thus, as early as 1892 the specific distribution of trout in New Zealand was showing signs of assuming its present form, and by 1910 the pattern was virtually complete. This pattern is obviously closely related to the nature of the first liberations made in each area and there would therefore be a temptation to regard this as the deciding factor. Further consideration suggests, however, that this may be largely fortuitous and that ecological factors have largely determined the present distribution of trout. The coincidence between the liberation pattern and the present distribution may arise partly from an unusually early appreciation of the importance of the ecological factors. The decision of the Auckland Acclimatisation Society to concentrate on rainbow trout seems to have been largely produced by the failure of their first small liberations of brown trout to achieve the spectacular success which had occurred farther south.

After trout stocks had become established, there was a long period during which the liberation of hatchery-produced fry was the main method of fisheries management practised in almost all parts of New Zealand. This period extended up to at least the middle 1930's, although since then there has been a gradual decrease in the amount of hatchery work in most parts of the country. During this period most acclimatisation societies were liberating both brown and rainbow trout, and, although it is impossible to trace all liberations made in every water in New Zealand, it is likely that in the great majority of waters both species have at some time been liberated, regardless of which form was originally established there. In some instances mixed populations have developed, and in a few of these, such as Lake Taupo in the North Island and Lake Te Anau in the South Island, the second species, in each case rainbow trout, has rapidly become dominant. In the majority of waters, particularly in the brown-trout area, the second species to be introduced has failed to establish itself. This suggests that the nature of the environment has played a major part in determining which species has finally occupied any particular water, although the species originally liberated was frequently that most suited to the environment.

Evidence of the importance of the environment is also provided by the waters containing mixed populations. Most of these populations have been in existence for many years and it is believed that their composition is now generally stable. Mixed populations are most commonly found in rivers about the dividing line. In river systems to the north of the line, such as the Tukituki and the Waipa, rainbow trout predominate. In the upper Wanganui system, which lies on the line and is immediately south of the Waipa subsystem, the species are in approximately equal numbers. In the Manawatu system, which adjoins the Tukituki on the south but is evidently south of the line, brown trout are completely dominant although a few rainbow are present. Farther away from the line in either direction mixed populations become less common and dominance is generally more complete. These effects in stable populations indicate clearly that environmental factors have determined the balance between species in mixed populations and therefore that they are largely responsible for the distribution pattern over the country as a whole.

This study of the present distribution of the various species of trout in New Zealand has been based almost entirely on their occurrence in anglers' catches. While it has yielded strong evidence that this distribution is due to environmental factors it can give no direct evidence as to the nature of these factors. The separation into northern and southern species immediately suggests the existence of climatic and particularly of temperature factors, and it has been stated (Needham, 1938) that the rainbow trout can withstand higher temperatures than the brown trout. The effects of temperature on fish are not, however, limited to the mortality caused by excessively high temperatures, and it has been suggested by other workers that the brown trout normally thrives in warmer waters than the rainbow trout. The only comprehensive data regarding temperature distribution are the meteorological records of air temperatures. Study of the monthly isotherms (Kidson, 1950) shows that in the region of the boundary between the brown-trout and rainbow-trout areas the minimum monthly mean temperatures are about 47°F. (8°C.) and are slightly higher on the west coast than on the east. The maximum monthly mean temperatures along this line are about 63°F. (17°C.) and are rather higher at the eastern end. The isotherms assume very irregular shapes which change greatly from month to month, and there is no indication that the boundary between species corresponds to any significant line in temperature distribution. In these meteorological data temperatures have been reduced to sea level, and the actual temperatures would be considerably less along the central part of the line where the land rises to a considerable height. This effect would still further reduce the agreement between the trout boundary and the temperature distribution.

Since there are no clearly defined climatic factors involved, a study of the causes underlying the distribution of the principal species of trout in New Zealand would have to take into account a great variety of possible factors. Preliminary considerations suggest the possibility that the nature of the rocks of the drainage area may have some influence, possibly through the nature of river-bed sediments formed by their breakdown.

There is one known difference between the two species which could affect the balance between them. Throughout New Zealand the rainbow trout consistently spawns later than the brown trout (July to September as against May to July). Where suitable spawning areas are limited in extent the later-spawning species would have an advantage since it would tend to dislodge and destroy the eggs of the earlier spawners. In waters where other environmental factors were evenly balanced this effect might enable the rainbow trout to become dominant.

An ecological study of the factors determining the distribution of brown and rainbow trout in New Zealand would include examination of the growth of each species under various environmental conditions, particularly in waters where balanced populations of the two species existed. Unfortunately no useful data on this point are yet available, but the diaries do provide information on the size normally reached by each species at capture. Owing to the scarcity of populations in which both species are reasonably abundant, few waters have given large enough samples of each species to make comparison possible. The results for the seven waters which gave the best samples are summarised in Table 17. In these waters the most usual condition is for the average length of the brown trout to exceed that of the rainbow trout, usually by about 1½ inches. This occurs in four of the waters studied; in two others there is no significant difference in the species, and in only

Table 17. Comparison Between the Mean Lengths of Brown and Rainbow Trout Caught in the Seven Rivers Which Yielded Adequate Amounts of Data

Water	Brown Trout		Rainbow Trout	
	Number	Mean Length (Inches)	Number	Mean Length (Inches)
Waipa	100	17·44	137	15·69
Wanganui	563	15·60	510	15·75
Whakapapa	41	17·17	99	18·36
Manganui-o-te-Ao	97	20·12	330	18·59
Rangitikei	75	17·97	302	16·03
Waimakariri	225	16·05	42	15·64
Waiau	951	17·26	229	15·39

one, where the sample is relatively small, is the mean length of rainbow trout greater than that of brown trout.

The relation between the mean lengths shows no evident correlation either with the specific composition or with geographical features. Three of the waters, for instance, are in the same river system; they are the Wanganui and its tributaries, the Manganui-o-te-Ao and the Whakapapa; despite their geographical relationship, they show different relations between the mean lengths. In the first there is approximate equality, in the second brown trout are larger, and in the third rainbow trout are larger.

Study of the detailed length distributions shows some tendency for the brown-trout curve to have a rather broader peak before entering the almost exponential descent shown in Figs. 5 to 8. The curve for the rainbow trout generally, but not always, has a sharper peak. It seems possible that the more rapid decrease in abundance of large fish which tends to occur in the rainbow trout may be due to some extent to its greater vulnerability to angling.

The small amount of data which have been available for analysis shows that the two species tend to have fairly similar size distributions when they inhabit the same water, and that such differences as occur show no obvious correlation with any other factors that have been studied.

5. COMPARISON WITH THE PAST

SUMMARY

This can be based only on the comparison of present data with contemporary unbiased records of angling results in earlier periods. Data now accumulated allow comparisons to be made for size of fish, and sometimes for rate of catch, in 43 waters in 13 districts (Appendix 3).

In 10 out of 16 waters for which rate of catch can be compared it appears to be decreasing, and no significant change occurs in the others. No waters show an increasing rate of catch.

Of the 23 waters in which size of fish shows indications of a change, it had increased in 15 and decreased in 8. In the other 20 it shows no significant or regular change.

The most usual tendencies shown by comparison are therefore for a decrease in rate of catch, and for no change or an increase in the size of fish. Changes are rather more evident in the North Island than in the South Island, where constancy is more usual.

Changes in anglers' results are caused not only by changes in the state of fish stocks, but also by factors directly affecting the angler. Among the factors are the regulations controlling fishing and, in particular, bag and size limits. From about 1900 up to the time of the diary scheme, there was a general tendency for the gradual tightening of restrictions by the reduction of bag limits and the increase of size limits. Both these changes will tend to reduce the rate of catch (per day but not per hour for bag limit changes) and to increase the size of fish. As these were the types of changes which most usually occurred, the data were examined in detail to try to determine how far the observed changes in anglers' catches were the result of changes in regulations.

The increase in average size of fish caught does not seem to be generally due to the raising of the size limit, since in only four out of fifteen waters where increases occur can it be fully accounted for in this way. The decrease in rate of catch also seems to be largely unrelated to changes in regulations. In five of the ten waters showing well-marked decreases there was no change of regulations at the appropriate time. In the other five, the change in regulations would fully account for the decreased rate of catch in only three cases.

In New Zealand, as in many other countries, there has been for many years a widespread belief that the fisheries were undergoing a progressive deterioration in the size or the abundance of fish, or both. The validity of such a belief can only be tested effectively by comparison of the results obtained by anglers at different periods. For this purpose it is necessary to have for comparison records which give a truly representative sample of conditions during the period concerned and are not merely records of selected days. The main sources of such records, in the absence of organised creel-census schemes, are the diaries of individual anglers and sometimes the results of angling competitions. The organised keeping of diaries with the deliberate object of providing records for research purposes began in New Zealand soon after 1930, at first as local schemes and ultimately as the general scheme which forms the main subject of this report. For the period before 1930 the only records available are those kept by individual anglers for their own interest. Only a very small proportion of anglers keep such records, and of the records which are kept few ever become available for research.

Hobbs (1948) collected many records of the catches of New Zealand anglers. From his study of the results he concluded that, although the size of fish in some waters declined during the first few years after establishment, it was rare for such a decline to continue after about 1900 and that the size of fish had generally not changed appreciably since that date. The number of fish caught per day or per hour had, on the other hand, shown a continued decline in a greater number of waters, although this decline had generally not been great and was proportionately much less than the increase in the number of anglers during the period.

The present work has enabled the comparisons published by Hobbs to be added to in various ways. For the waters for which comparisons have already been made,

Table 18. The Numbers of Waters in Each District for Which Records Show Various Kinds of Changes in Anglers' Catches

District	Rate of Catch				Average Size			
	Increasing	Decreasing	Constant	Irregular	Increasing	Decreasing	Constant	Irregular
Ashburton	..	..	..	..	1	1	1	..
Auckland	..	5	1	..	5	..	2	..
East Coast	..	..	..	1	..	..	1	..
Hawke's Bay	..	1	..	..	1	..	..	..
Nelson	..	..	..	..	..	..	1	..
North Canterbury	..	1	..	..	2	1	1	..
Otago	..	..	3	..	2	2	5	1
South Canterbury	..	..	..	..	1	2	..	..
Southland	..	1	..	..	2	..	2	..
Waimarino	..	..	..	..	..	..	1	..
Waitaki	..	..	1	..	1	..	..	..
Wellington	..	2	..	..	..	1	1	1
West Coast	..	..	..	..	..	1	1	..
Otago-Southland	..	..	..	..	..	..	1	..
Auckland-Waimarino	..	..	..	..	..	..	1	..
Total	..	10	5	1	15	8	18	2
North Island	..	8	1	1	6	1	6	1
South Island	..	2	4	..	9	7	12	1

it has extended by about seven years the period covered by the comparison. For some other waters data were previously available for only a single period; in these cases the general diary scheme had added data for a second period and so enabled a comparison to be made. Finally, the publicity which the general scheme gave to the value of diaries caused several anglers to make available for analysis personal records which sometimes covered quite long periods. The largest group of waters for which comparisons are now possible for the first time is formed by those for which large samples of the scales of rod-caught fish are preserved in the collections of the Marine Department. Most of these scale collections were made between 1932 and 1937 at a time when growth studies, based on scale reading, formed a major part of New Zealand's fisheries research programme. Although no comparison of rates of catch is possible in these cases, the size of each fish from which scales were taken was recorded and the results can therefore be compared with the sizes of the fish recorded under the general diary scheme.

The data regarding those waters for which information is now available for more than one period are summarised in Appendix 3 (a). The early data on rates of catch are sometimes available as fish per day and sometimes as fish per hour. The results for the recent general diary scheme have in each case been presented in the same form as the early data. In many cases the early records of size of fish give only their weights while the results of the organised diary schemes are expressed as lengths. Where most of the data for a water are mean weights, the mean length obtained from the general diary scheme is given in italics and, to enable a comparison to be made, it is followed by the weight of a fish of that length with a condition factor of 120 on the cm.-gm. scale. As explained in a previous section this gives an estimate of the mean weight of the same sample of fish which is probably correct to within 10 per cent.

The changes which have occurred in each acclimatisation district are discussed in detail in Appendix 3 (b), and the results are summarised in Table 18. In the table, waters are classified as showing an increase or decrease only if the differences are sufficiently great to be unlikely to be caused by sampling errors or if a series of figures show a continuing trend. Early variations are not considered if later results indicate that conditions are now stable. The changes are classified as irregular if there is evidence that changes in one direction have later been followed by a reverse movement which is still continuing. Examination of the table shows that where there is any change the most usual trends are for a decrease in the average rate of catch and an increase in the average size of fish caught.

The daily or hourly rate of catch shows a definite decrease in eight out of ten North Island waters; in one, the Waitawheta, it shows no change; and in one, the Hangaroa, it has varied irregularly, showing first a decrease and then an increase to an even higher level than that prevailing in the first period. In the South Island, four out of the six waters for which data are available show no change; the other two, the Hororata and the Otapiri, show a definite decrease.

The tendency for average size to increase is more definite in the North Island. Here, six of the eight waters which show some change have undergone an increase in average size and there are six showing no change. In the South Island there are twelve waters in which average size is constant, and among the other seventeen the size has increased in nine. This frequent increase in the average size of fish caught by anglers suggests that in many waters there has been, in recent years, some change in the nature of the trout populations. Since about 1930 there has, however, been

a fairly general tendency for the minimum legal size to be increased. This change, by removing from the catch the smallest size group, will tend to raise the average size of the fish kept, and it is therefore desirable to examine the extent to which it has contributed to the observed increases in mean length. One such case has already been discussed. This was the Kakanui river in the Waitaki district, where the observed change was greater than would be produced by the increase in the size limit. The other waters where increases have been observed will be discussed district by district.

In Ashburton, where a substantial increase is shown by the Ashburton river, the size limit for this river has remained unchanged at 10 inches since 1931 and therefore had not affected the results.

In Auckland the size limit was raised from 10 inches to 12 inches in 1932. Although the earliest records from the Oraka and the Waihou refer to the period prior to the change, well-marked increases have occurred in both these rivers and in three others since that time.

In Hawke's Bay the size limit for rainbow trout was raised in 1932 from 9 inches to 12 inches. In the Tukituki, where this species forms over 90 per cent of the catch, the substantial increase in size which has been recorded since 1921–31 may have been partly due to this change in regulations. Since the 1947–52 records show only about 15 per cent of undersized fish with the 12-inch limit, the addition to catch of this proportion of fish, even if they were all just takable under a 9-inch limit, would only depress the mean weight by about 5 per cent. The large increase which has occurred is therefore mainly due to a change in the state of the trout population.

In North Canterbury the size limit was raised from 9 inches to 10 inches in 1933, and then to 11 inches in 1936. The records for the Cam and Hororata, which show increases, therefore bridge the period when the size limit was increased. For the Cam the individual lengths of all fish were recorded for each period and the effect which a higher size limit would have produced on the earlier catches can therefore be determined. The 1917–19 records include no fish of less than 12 inches, and a limit as high as this would therefore have had no effect on the mean length. The 1928–36 records, on the other hand, include 21 fish of 9 and 10 inches, and if these had been excluded by an 11-inch limit the mean length would have been 16·15 inches, which is a very similar figure to that recorded in 1948–52. No individual lengths are available for the early catches from the Hororata, but the percentage of undersized fish taken in 1948–52 (42·5 per cent) is very high, being considerably greater than that recorded for the Cam (25·2 per cent). It seems not unlikely, therefore, that in this river also the change in size limit has contributed largely to the apparent increase in the average size of fish caught and kept by anglers.

In Otago the size limit was increased from 9 inches to 10 inches in 1932. Two waters in this district show increases. In one of these, Poolburn Dam, the change in size has taken place since the regulations were altered. In the other, the Wyndham, the increase in size seems to have coincided with the raising of the size limit. It seems possible, therefore, that in this river the change in regulations has contributed towards the increased average size, although it is unlikely that it is the sole cause. The 1946–52 records show that 23 per cent of the fish taken in the Wyndham during this period were undersized, and the addition of this proportion of 9-inch

fish to the recorded catch for this period would only reduce the average weight by about half the amount of the increase.

The size limit in South Canterbury was raised from 9 inches to 10 inches before the opening of the 1931 fishing season. Re-examination of the original data for the Opihi shows that most if not all of the fish shown for the 1930–40 period in the appendix were taken after the limit was changed. The substantial increase recorded from this river was therefore not caused by the change in regulations.

In Southland the size limit was increased from 9 inches to 10 inches in 1928 and then to 11 inches in 1935. It was raised again to 12 inches in 1951, one year before the general diary scheme was concluded, but this final change had little effect on the average length of the recorded fish. In this district increases in mean length are shown by two rivers, the Aparima and the Oreti, and in both the increases occurred more or less simultaneously with the change in the limit. In both these rivers anglers now take a high proportion of undersized fish (34 per cent), and if many of these are between 9 and 11 inches and so previously takable, the average size under a 9-inch limit would be little more than was actually recorded when such a limit was in force. It is therefore likely that in this district the increase in average size is largely the result of the changes in the size limit.

Thus in only two districts, involving four waters, does the increase in average size seem to have been mainly caused by a rise in the size limit. In two other waters such a change in the regulations may have caused part though not all of the change. In the other nine waters the increased average size seems to be solely due to changes in the nature of the trout population.

Changes in regulations could have affected the rate of catch as well as the average size of fish taken. Changes in the bag limit could affect the daily but not the hourly mean catch. Changes in the size limit could affect the rate of catch whichever way it was measured. During the last twenty-five years there has been a tendency in almost all districts towards tightening restrictions by increasing size limits and reducing bag limits. Both of these changes would tend to reduce the rate of catch; it is therefore interesting to examine the data for those waters where decreasing rates of catch are recorded in order to find out how far the change is likely to have been due to alterations in the regulations.

In the Auckland district five waters show decreases in the hourly rates of catch. In three of these, the Awakino, Kauaeranga, and Mangaotaki, the same bag and size limits were in force in the earlier and later periods. In the other two the bag limit has been constant throughout, but the size limit has been changed from 10 inches to 12 inches between the first and last periods. In the Oraka the reduction in rate of catch is so small as to have doubtful significance and could easily be due to the increase in the proportion of fish returned as undersized since this is now over 50 per cent. In the Waihou the data show a substantial decrease in the average daily bag between 1928–32 and 1948–52. The percentage decrease happens to be exactly the same as the percentage of undersized fish recorded in 1948–52 under the 12-inch limit. If all these rejected fish had been takable under the previous 10-inch limit this would fully account for the change in rate of catch. Although some of these fish would almost certainly have been less than 10 inches long it is not possible, in view of the sampling errors, to reject the simple hypothesis that the change in regulations was largely responsible for the reduction in rate of catch.

In Hawke's Bay the reduction in rate of catch in the Tukituki was contemporaneous with the raising of the size limit for rainbow trout, which form 91 per

cent of the catch, from 9 inches to 12 inches. The rate of catch shows a reduction of 29 per cent in the samples available and in 1947–52 the recorded catches included 38 per cent of undersized fish. The reduction in rate of catch could therefore be explained in this case also as arising from the increase in the size limit.

In the North Canterbury district the records show a large reduction in the average daily bag between 1920–31 and 1948–52 on the Hororata. In the interval there were two changes in regulations, both of which would tend to produce a reduction in the daily bag. The size limit was raised from 9 inches to 11 inches and a bag limit of 10 fish per day was imposed, there being no limit during the first period. A recent paper (Allen, 1954) has provided curves which may be used to provide an estimate of the reduction in catch which will be produced by application of any given limit to a particular fishery. Reference to these curves shows that, where the unrestricted mean daily bag was 3·67, application of a bag limit of 10 would reduce the catch by only about 3 per cent. During 1948–52, under the 11-inch limit, about 42 per cent of fish caught were returned as undersized. It appears, therefore, that if the trout population were unchanged the combined effect of the two changes in regulations would be to reduce the mean daily bag by about 45 per cent at most. The actual reduction shown by the samples available is slightly over 60 per cent. Allowing for sampling errors it seems possible, although not certain, that population changes, as well as alterations in the regulations, have contributed towards the reduction in daily bag shown by the data for the Hororata.

The only water in Southland for which comparative figures on daily rates of catch are available is the Otapiri. For this water two early periods give figures which are in very good agreement and these are followed by much lower figures for 1947–52. For the three periods the size limits were successively 9 inches, 10 inches, and 11 inches, while the bag limits were successively unrestricted, 25 fish, and 15 fish. Both series of changes would tend to reduce the mean daily bag. Application of a bag limit of 15 fish to a fishery giving a mean daily bag of 12·9, as the 1890–1902 records show, would probably cause a reduction of about 25 to 30 per cent. In 1947–52, the percentage of undersized fish recorded under the 11-inch limit was about 33 per cent. If many of these fish were takable under a 9-inch limit, it appears that the changes in regulations would account for a considerable part of the reduction in mean daily bag between 1890–1902 and 1947–52. Since the regulations were at an intermediate level in 1930–32, the small change in daily bag between 1890–1902 and this period would be more than accounted for by the changed regulations. The greater change in the bag during the second interval suggests that this may have been also partially due to a change in the trout population.

The results for the Wellington district are expressed as fish per hour and are therefore likely to be influenced only by changes in the size limit. Both the Makakahi and the Manawatu show a progressive reduction in the rate of catch extending over three periods. Between the first two periods the size limit was raised from 9 inches to 11 inches and it remained at this level for the third period. In both waters the reduction in rate of catch is considerably greater in the second interval, when no change in regulations occurred, than it was in the first. The reduction in rate of catch in these waters was therefore primarily due to changes in the fish population.

To sum up: ten waters in five districts show apparently significant decreases in rate of catch. In five waters in Auckland and Wellington districts the changes have occurred at a time when there was no change in regulations which could have contributed to them; they must therefore have been due to changes in the state of

the trout population. On the other hand, in three waters in Auckland and Hawke's Bay there were simultaneous changes in bag and size limits which could have produced the entire recorded change in rate of catch. The only two South Island waters where a decrease was recorded, one in North Canterbury and one in Southland, occupy an intermediate position in this respect. In both of them there were changes in bag and size limits which would have tended to reduce the rate of catch, but in neither of them would the alteration in regulations have been likely to reduce the rate of catch to the extent actually recorded.

6. SHORT-TERM CHANGES

SUMMARY

Few waters provided sufficient data to show whether any significant changes in anglers' results occurred during the period of the diary scheme. For the Mataura there is evidence of a steady decline in the size of fish caught and comparison of data from four sources shows that it is highly significant. Three other waters show fairly continuous declines in average length although the significance cannot be tested. On the other hand, two waters show steady increases in size over the period. Many other waters which gave equally good series of data show no sign of a change.

None of the waters examined show any continuing trend in the rate of catch during the period of the diary scheme. In some cases the irregular variations from season to season seem to be significant, and in a group of four adjacent rivers in South Otago these variations follow much the same pattern. Comparison with climatic factors shows that the rate of catch varied from year to year in much the same way as did the mean air temperature during the seven months of the angling season. This may suggest that the variations in rate of catch were produced more by changes in suitability of the weather for angling than by changes in the fish stock.

The previous section has dealt with changes in anglers' catches which were revealed by comparison between the results of the general diary scheme and records, obtained from various sources, for the same waters at earlier periods. It has shown that in some waters definite changes in average size or in rate of catch have occurred. Most of the significant changes took place over periods of twenty years or more, although a few occurred within shorter periods. The period covered by the general diary scheme was relatively short; it extended over four or five seasons in most districts. To become apparent within such a short time changes must either be relatively great or occur in circumstances which enable their significance to be tested with unusual accuracy. Both the large size of the sampling errors and the difficulty of assessing them with any precision contribute to the difficulty of detecting significant changes in any of the characteristics of angling catches which can be extracted from the records.

The extent of the sampling errors has been discussed in previous sections. It was pointed out that the number of independent sources which had provided data for the Mataura River gave an unusually good opportunity of assessing the significance

Table 19. The Variation From Year to Year in the Mean Length of Trout Caught in the Five Waters Which Showed Most Definite Trends

District	Water	1946–47		1947–48		1948–49		1949–50		1950–51		1951–52	
		Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)	Number of Fish	Mean Length (Inches)
Nelson ..	Buller	115	18·76	212	18·81	308	19·46	248	19·11	198	19·81	108	20·47
	Motueka	197	17·97	393	17·66	685	17·00	692	16·91	1,193	16·81	1,035	16·85
Otago ..	Clutha	253	19·67	389	17·33	586	16·37	430	15·99	878	14·99	702	14·71
	Mahinerangi-Waipori	81	14·60	69	15·75	99	15·56	148	16·37	315	16·05	338	16·41
Southland..	Aparima	..	..	602	14·40	544	14·31	504	14·42	525	13·98	704	13·87

Table 20. The Variation From Season to Season in the Rate of Catch for Four Adjacent Rivers

River	1946–47		1947–48		1948–49		1949–50		1950–51		1951–52	
	Hours	Fish Per Hour	Hours	Fish Per Hour	Hours	Fish Per Hour	Hours	Fish Per Hour	Hours	Fish Per Hour	Hours	Fish Per Hour
Pomahaka	701	0·57	1,675	0·82	2,183	0·89	2,144	1·07	2,050	1·00	1,361	0·97
Waipahi	353	0·37	806	0·82	1,200	0·89	860	0·81	683	1·05	342	0·85
Wyndham	93	0·58	289	1·18	328	0·66	241	0·85	186	1·10	165	0·83
Mimihau	53	0·83	251	0·96	228	0·85	278	1·52	171	1·35	396	1·05

ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square	*F*
Years	5	1,461	6·06**
Rivers	3	970	4·02*
Discrepance	15	241	..

of the variation in mean length for that water. Analysis of variance gave a value of F for the four seasons 1947–48 to 1950–51 of 2·04. Although this is less than the value for 95 per cent probability it is sufficient to suggest that there may have been actual changes in the state of the trout population from year to year during the period studied. The likelihood of this is increased both by the tendency for the annual means to form a descending series and by the fact that the less complete data for the seasons immediately preceding and following the main results also fit in with this series. There is therefore reason to believe that the average size of fish taken by anglers in the Mataura was decreasing steadily during the period of the diary scheme.

A few other waters also appear to show progressive changes in the size of fish during this period, although no statistical test of significance is possible. These results are summarised in Table 19. The Buller and the Mahinerangi-Waipori system both show progressive increases from year to year which total nearly 2 inches over the whole period. No earlier data are available for the Buller but comparison with Appendix 3 (a) suggests that in the Mahinerangi-Waipori system the size of fish declined during the early 1940's and rose again to its earlier level towards the end of the decade.

The decrease in mean length in the Clutha is much greater than any other change recorded during this period. It is possible that it has been produced partly by changes from year to year in the methods used or the areas fished by the anglers who sent in diaries, but it is so continuous that it seems likely to be due, at least in part, to changes in the trout population. The decreases in the Motueka and the Aparima are much smaller, and it is only their continuity and the relatively large size of the samples which justify their inclusion in the table. If the apparent decrease in the Aparima is real it represents a reversal of trend, since Appendix 3 (a) shows that just prior to this period there had been a rise in the size of fish in this river.

Most of the other waters, including those listed in Appendix 3 (a), have not yielded sufficient data to show whether any changes were taking place during the period of the diary scheme. For the Makakahi in the Wellington district there is some indication that the downward trend in size during the 1940's has ceased and an upward movement is commencing. In a few other waters where fairly definite changes were shown by earlier comparisons good samples of data do not suggest that any further change occurred during 1947–52. These waters include the Awakino, Tukituki, Mimihau, Wyndham, Opihi, Oreti, and Manawatu. In no other waters are the data sufficient to give any satisfactory indication of conditions.

The evidence of current changes in rate of catch is even less than that for changes in average size, which was discussed above. None of the waters for which relatively large amounts of data are available show any sign of a continuing trend either upward or downward during the 1947–52 period. Thus, it does not seem that the general long-term tendency for rates of catch to decrease that was noted in the previous section is at present proceeding fast enough to produce any measurable effects during the recent 5-year period. Where the data are sufficient, they suggest that, apart from minor year-to-year variations which are generally of doubtful significance, the rate of catch has stayed at about the same level throughout the period studied. The only notable exceptions are the Makakahi and Manawatu in the Wellington district, where the recent decreases referred to in the previous section continued during the period 1948–52.

The significance of changes in rate of catch from season to season has been discussed in an earlier section, and it was pointed out that even where a change was great enough to have statistical significance it did not necessarily imply that there had been a corresponding change in the state of the fish population. Many other factors could contribute to the result; some of these, such as angling skill, methods used, etc., are peculiar to the particular sample; other such as weather and water conditions may apply to all angling in that season, so that in these respects the sample is representative of the total. It is not usually possible to determine whether erratic variations from season to season signify changes in general conditions or not, but one series of data has been found where the variations seem to have general significance. In this series four adjacent waters, the Pomahaka, Waipahi, Wyndham, and Mimihau, seem to show similar variations from season to season throughout the period studied. These are rather similar streams, containing similar fish populations, and their watersheds are contiguous and of similar terrain, although the first two drain eastwards into the Clutha and the last two westwards into the Mataura. Table 20 shows the amount of data and the mean catch per hour in each river for the six years for which data are available. The analysis shows that although the variances due both to years and to rivers reach significant levels, that for years is considerably the larger, the value of F being well in excess of the 1 per cent level. It appears very probable, therefore, that the influences affecting the variation from year to year in the rate of catch were substantially similar in these four rivers. Although the same anglers fished these streams to some extent, the bulk of the records for the different rivers came from different groups of anglers, and it is therefore unlikely that the identity and characteristics of the diarists contributed to any important extent to the common features of the variation from year to year in rate of catch. There is no direct evidence as to whether the trout populations fluctuated in a similar way to the rate of catch. If they did show common variations it would seem that they were responding to common environmental factors since, even if the populations of streams in the same system were regarded as common, the two pairs of waters in this instance are completely independent as they enter rivers which join the sea 70 miles apart. The most probable factors which would affect all four waters similarly are various aspects of the weather. These could operate either through the trout population, or directly on angling catches by producing more or less favourable conditions for fishing.

Many different aspects of the weather could affect trout stocks or angling success, and no very clear correlation between rate of catch and weather characteristics is likely to be obtainable. The New Zealand Meteorological Service has provided data for Gore, which lies within 25 miles of most points in the four drainage areas. A number of the principal features of the weather have been examined for the period 1946–52, and the only one which shows any sign of similar variations is the daily mean temperature during the seven months of the fishing season. In Table 21 the mean temperature for each season is compared with the mean of the rates of catch for the four rivers. It appears that they tend to follow a similar course.

The direct correlation ($r = 0{\cdot}78$) is just below the 5 per cent level of significance, but in view of the exponential nature of many temperature effects the correlation coefficient has been calculated for the temperature - log. rate relationship. The value of r (0·86) thus obtained is significant at the 5 per cent level. The parallel variation is therefore close enough to give support to the suggestion that the similarity between the four streams is due to meteorological factors. Since the best correlation is with

Table 21. Comparison of Mean Air Temperature at Gore for the Seven Months of the Angling Season, With the Combined Mean Rate of Catch for the Pomahaka, Waipahi, Mimihau, and Wyndham

Season	1946–47	1947–48	1948–49	1949–50	1950–51	1951–52
Fish/hour	0·59	0·95	0·82	1·06	1·13	0·93
Mean temperature (°F) ..	53·5	56·0	54·2	55·1	55·5	54·2

weather conditions during the same season, it is more likely to arise from the influence of the weather on the suitability of conditions for angling than from effects on the size of the fish population.

IV THE ANGLING EFFORT

1. THE INDIVIDUAL ANGLER

SUMMARY

The number of days recorded as fished in one season by one angler varied from 1 to 143. The distribution curve conforms closely to the negative binomial distribution with a value of k of about 2·5, and with the average number of days fished in a season ranging between 20 and 30 in most districts. The average number of days fished in a season tends to increase with the number of seasons for which an angler kept a diary. From this it is inferred that diarists fished more often than the true average angler, and by fitting a regression line to the number-of-seasons / number-of-days data, an estimate is made of the average number of days fished by anglers who never kept a diary, and this is taken to provide an estimate for the whole population. The correction obtained in this way to the average for the diarists is usually −5 to −10 days. The correction is negligible in relation to the sampling error for samples of anglers less than about 45. More precise estimates can be made by applying to the data a transformation appropriate to the negative binomial distribution, but the difference in the results is too slight to justify the time involved.

The length of the fishing day varies from day to day and from angler to angler. The average length also varies significantly from district to district, being highest in the extreme north and south, intermediate in the centre of the South Island and lowest in the north and west of the South Island and the south of the North Island. District means range from about 2·4 hours to about 4·5 hours. There is no evidence that the diarists are not representative of the whole angling population as regards length of fishing day.

The shape of the distribution curve for length of day varies greatly for different waters, being sharply peaked at about 2 hours when the mean is low and flat-topped or sometimes bimodal when the mean is greater than 4·0. To interpret these curves angling days are classified as "half-days" (4 hours or less) or "whole days" (over 4 hours). Where the average day is long there may be up to 50 per cent of whole days, but where it is short few whole days are recorded. The distribution curves for individual anglers conform very closely to the general curves for the waters they fish.

There is a tendency for the length of day to increase with the distance the angler has to travel to reach the water. There are also differences between the average length of day for different angling methods; the nature of these differences varies somewhat from water to water, but the fly-fishing day is usually the shortest. These differences due to method and distance are, however, small compared to

differences in average length between acclimatisation districts. Established local custom seems to be the most important factor in producing these.

It is a truism that the total angling effort in any district or on any water is the sum of the efforts of all the individual anglers who fish there, but, except when complete control of angling can be organised, the total effort can often be estimated only by the study of some of the individuals. This is particularly so when, as in the present work, the original data are derived from a relatively small group of anglers but contain an almost complete record of their fishing. Although its length may vary greatly, the fishing day is the most natural unit and therefore forms the best basis for the study of the fishing effort. In Table 22 the distribution of number of days fished in a season is summarised by districts for all the complete diaries available. The range is considerable, the number of days recorded in a season varying from 1 to 143. The distribution is obviously asymmetrical, having a long tail on the upper limb.

Many such distributions have been shown to be fitted satisfactorily by the negative binomial $(q - p)^{-k}$, where $p = m/k$ and $q = (1 + p)$. This has therefore been tested for the present series by the method of Bliss and Fisher (1953). For this purpose the Nelson and Southland series have been used since the amounts of data are relatively large and their means occur at the high and low ends of the usual range. The values obtained for the parameters were: Nelson, $m = 20{\cdot}37$, $k = 2{\cdot}33$; Southland, $m = 31{\cdot}33$, $k = 2{\cdot}57$. Application of the chi-square test gives probabilities of more than 0·4 and 0·1 respectively, while tests of the second and third moments also show that the original distributions conform satisfactorily to the negative binomial. The difference between the values of k for the two series is not significant. It seems likely therefore that the number of days fished in a season by a group of anglers may tend to be distributed according to the negative binomial with a value of k of about 2·5.

The data are derived from the records of all anglers who sent in complete diaries for one or more seasons during the period of the general diary scheme. They are to some extent selected, since they come only from those anglers who voluntarily maintained and sent in diaries. On general grounds it seems reasonable to expect that these would tend to be the most enthusiastic anglers and that they would fish more frequently than those anglers who did not keep diaries. The validity of this belief has been examined in two ways.

If the anglers who kept diaries fished more often than the average, it seems a logical extension that those who kept diaries for a larger number of seasons should fish more often than those keeping diaries for fewer seasons. This hypothesis has been tested for those districts which returned the greatest number of diaries. The results for the Nelson and Otago districts are summarised in Tables 23 and 24. It is evident in each case that there is a tendency for the mean number of days fished per season to increase with the number of seasons recorded.

A regression analysis has therefore been made in Appendix 2 (b) for the seven districts which gave the greatest amounts of data, and in every district but one a significant positive regression coefficient is found. This indicates that anglers keeping diaries for a larger number of seasons generally fish for more days per season than those keeping diaries for a shorter time. It therefore supports the hypothesis that those anglers who keep diaries fish more frequently than those who do not. Some more direct evidence, although on a small scale, is also available on this point. In

Table 22. The Distribution for Each District of Number of Days Fished by Individual Anglers in a Season

District	Number of Days Fished in a Season									Total Number of Diaries	Mean Number of Days Per Season
	1–5	6–10	11–15	16–20	21–30	31–40	41–50	51–75	76–		
Ashburton	5	5	1	4	4	2	2	..	1	24	19·9
Auckland	11	13	17	11	22	13	4	3	3	97	22·5
East Coast	1	7	4	1	2	..	..	..	..	15	12·4
Hawke's Bay ..	1	8	4	6	9	3	3	5	8	47	36·1
Hawera	1	..	4	2	3	1	2	1	..	14	25·7
Marlborough ..	..	2	3	4	1	1	..	1	..	12	21·2
Nelson	19	45	46	40	45	26	9	10	1	241	20·4
North Canterbury ..	3	4	10	10	3	3	..	2	..	35	18·5
Otago	31	35	65	62	103	62	33	39	5	435	26·7
South Canterbury ..	2	4	7	9	23	7	2	2	1	57	23·9
Southland	9	9	10	11	30	34	15	15	3	136	31·3
Taranaki	..	8	7	..	4	2	2	4	..	27	25·0
Waimarino	18	19	11	18	22	7	5	4	1	105	19·5
Wellington	8	11	9	18	19	6	5	7	..	83	23·1
West Coast	2	1	2	4	8	8	2	..	..	27	25·0
Westland	..	..	1	1	2	1	..	..	..	5	23·8
Total ..	111	171	201	201	300	176	84	93	23	1,360	24·5

Table 23. The Distribution of Number of Days Fished in a Season by Otago Anglers Who Kept Diaries for Different Numbers of Seasons

Number of Seasons	Number of Days Fished in a Season									Total Number of Diaries	Mean Number of Days Per Season
	1–5	6–10	11–15	16–20	21–30	31–40	41–50	51–75	76–		
1	17	13	18	10	30	13	9	7	..	117	22·1
2	7	10	12	16	16	11	3	6	3	84	25·5
3	4	4	12	13	20	10	8	8	..	79	28·2
4	..	4	6	..	6	5	2	1	..	24	25·1
5	..	2	9	10	16	11	4	7	..	59	29·3
6	3	3	6	14	15	11	8	10	2	72	32·1

Table 24. The Distribution of Number of Days Fished in a Season by Nelson Anglers Who Kept Diaries for Different Numbers of Seasons

Number of Seasons	Number of Days Fished in a Season									Total Number of Diaries	Mean Number of Days Per Season
	1–5	6–10	11–15	16–20	21–30	31–40	41–50	51–75	76–		
1	8	17	9	6	7	1	2	..	1	51	14·7
2	9	6	16	7	9	4	1	1	..	53	16·1
3	2	4	7	6	9	13	2	5	..	48	27·4
4	..	6	2	5	8	3	2	1	..	27	24·4
5	11	8	10	8	3	..	..	..	..	40	17·8
6	1	4	6	4	2	2	3	..	..	22	28·2

Table 25. The Percentage Distribution of Number of Fish Caught in the Nelson District in 1949–50 by Anglers Who Sent in Diaries, and by Those Who Did Not Return Diaries But Were Subsequently Interviewed

	Number of Fish											Number of Anglers
	0	1–5	6–10	11–20	21–40	41–60	61–80	81–100	101–150	151–200	201–	
Diarists	..	9·5	11·9	35·7	16·7	9·5	7·1	2·4	7·1	..	..	42
Non-diarists	11·2	15·7	11·2	18·0	12·4	7·9	7·9	3·4	6·7	4·5	1·1	89

1950, shortly after the close of the angling season, a visit was made to the Nelson Acclimatisation District for the purpose of interviewing anglers who had not sent in diaries. About one-third of the anglers in the area were interviewed and these were chosen largely at random. Each angler seen was asked to estimate as closely as possible the number of fish he had caught in the preceding season. Table 25 shows the distribution of these estimates and compares them with the corresponding figures taken from the records of the anglers in the same area who sent in diaries for the 1949–50 season. Since these figures represent numbers of fish caught, and not days fished, they are not strictly comparable with those discussed earlier in this section, but the much higher proportion among the non-diarists of anglers catching less than six fish in the season suggests that the distribution based on the diary records may contain an insufficient proportion of anglers fishing only a few times in the season. It therefore supports the previous conclusion.

Table 25 also shows that among the non-diarists there was a group that caught more fish than any angler who sent in any diaries. In the absence of any detailed records from these anglers, it is impossible to be sure whether the high catches arose from a large number of fishing days, a long average day, an unusually high degree of skill, or some combination of these factors.

Since the diary records are probably deficient in anglers fishing only a few times in the season, the mean numbers of days per season shown in Table 22 will be higher than the true means for all the anglers in the district. An attempt can be made to determine the magnitude of the necessary correction. If the relation between seasons recorded and days fished is linear, then the constant terms in the regression equations in Appendix 2 (b) provide an estimate for these districts of the number of days fished by anglers who never returned diaries. As such anglers were in the great majority in all districts, this estimate may be taken also as an estimate for the entire angling population of the district. Table 26 shows for each of these seven districts, as well as for their combined results, the correction which is obtained in this way for the original mean number of days fished. Except for the anomalous South Canterbury results, for which the amount of data is relatively small, the correction is negative and less than 13; in most districts it is between 5 and 13. Comparison with Table 1 shows that the correction tends to be greatest when the proportion of anglers sending in diaries is least, and conversely. Statistically, the

Table 26. The Effect of Applying the Corrections Based on the Regression Equations on p. 145 to the Estimated Mean Number of Days Fished per Season for the Seven Principal Districts

District	Number of Complete Diaries	Diaries Per Angler	Mean Days Recorded	Corrected Mean	Correction
Auckland	97	2·30	22·5	9·7	−12·8
Nelson	241	3·07	20·4	14·5	− 5·9
Otago	435	3·10	26·7	21·2	− 5·5
South Canterbury	57	1·98	23·9	33·9	+10·0
Southland	137	2·05	31·3	19·0	−12·3
Waimarino	105	2·28	19·5	17·9	− 1·6
Wellington	83	2·00	23·1	10·2	−12·9
Mean	1,155	2·69	24·6	19·3	− 5·3

correlation, ignoring South Canterbury results, is just below the 5 per cent level of probability. Intrinsically, however, it is quite probable, since the smaller the proportion of anglers sending in diaries the greater the likelihood of the group's consisting mainly of very enthusiastic anglers who fish frequently.

If corrections were desired for the other nine districts, values of −5 to −10 days would appear to be appropriate in most cases according to the proportion of anglers contributing diaries, but, as the size of the sample decreases, the probable error of the original mean will increase until a point is reached at which it renders the proposed correction unimportant. For the seven principal series the variance ranges roughly from 200 to 400, with an average value of 285. For this variance, a correction of 5 will become equal to twice the standard error of the mean when the sample is reduced to 45. There is little justification therefore in applying the correction to the remaining nine districts.

It has been shown that the number of days fished per season is distributed according to the negative binomial. A bias is therefore introduced in the calculation of the regression lines, since this is based on the assumption of a normal distribution. The transformation given by Anscombe (1948) has been applied to the largest series of data to obtain more accurate estimates for the correction. The resulting figures differ by less than 1·5 from those given in Appendix 2 (b). These differences are well below the significant level, and it is therefore unnecessary to undertake the more laborious procedure involved in applying the transformation.

The effect of the transformation on the estimate of the minimum size of sample to which the correction for anglers not recording should be applied, has also been examined. The more exact method does not seriously alter the conclusions previously reached, although it allows rather greater latitude when the mean is small.

Obviously the length of time spent fishing varies from day to day even for one angler. In addition to this, there may be tendencies for the mean and the usual range to vary from one angler to another, and also from one water or one district to another. Table 27 shows the distribution by districts of the mean length of the fishing day in the 130 waters included in Appendix 1. There are considerable differences between districts. At one extreme is Auckland with a mean for the whole district of 4·19 and no waters with a mean less than 3·51; and representative of the other extreme is Nelson with a district mean of 2·92 and no waters more than 4·0. The other districts occupy intermediate positions but some general trends may be observed. Auckland, with a long average day, is the most northerly district, and East Coast, which lies in similar latitudes farther east, gives a similar result for the one water which has yielded adequate data. To the south of these two, in the remainder of the North Island and on the north and west coasts of the South Island, the average day is much shorter, being generally about 3 hours or even less. Farther south, however, the length of day tends to increase again, being about 3·5 hours in most of the districts on the east coast of the South Island and about 4 hours in the extreme south. These regional trends are clearly shown in the lower section of Table 27 in which the country is divided into four areas.

The implications of these differences in mean length of fishing day cannot be understood without knowledge of the way in which the length of day is distributed. Table 27 shows that in any one district there may be considerable variation between different waters. Distributions for entire districts would be the resultant of the different distributions for the various component waters and would have little value. Analysis has therefore been made of the distributions recorded for a number of

Table 27. The Distribution for Each District of the Mean Number of Hours Fished Per Day in Each of the Waters Included in Appendix 1. Also Within the Four Major Geographical Areas – Area 1: Auckland, East Coast; Area 2: Taranaki, Hawera, Waimarino, Hawke's Bay, Wellington, Nelson, Marlborough, West Coast, Westland; Area 3: North Canterbury, Ashburton, South Canterbury; Area 4: Waitaki, Otago, Southland

District	Mean Number of Hours Per Day											District Mean Number of Hours
	1·51–2·0	2·01–2·5	2·51–3·0	3·01–3·5	3·51–4·0	4·01–4·5	4·51–5·0	5·01–5·5	5·51–6·0	6·01–6·5	6·51–7·0	
Ashburton	..	..	1	2	..	..	..	..	..	..	..	3·42
Auckland	..	..	..	..	3	2	3	3	1	1	..	4·19
East Coast	..	..	..	..	..	..	1	..	..	..	..	4·15
Hawke's Bay	1	2	1	1	..	1	..	..	..	..	..	2·90
Marlborough	..	..	..	1	..	..	..	..	..	..	..	2·48
Nelson	1	4	4	4	3	..	..	..	..	..	..	2·92
North Canterbury	..	2	1	2	4	..	1	1	..	..	..	3·69
Otago	..	2	3	5	2	4	3	1	4	1	1	4·40
South Canterbury	..	..	2	2	2	1	..	..	..	..	..	3·51
Southland	..	..	..	3	3	7	1	..	..	..	..	3·73
Taranaki-Hawera	1	1	..	1	..	1	1	..	1	..	..	2·98
Waimarino	1	4	..	1	..	..	..	..	..	..	..	2·35
Waitaki	..	..	..	..	..	..	..	..	1	..	..	5·63
Wellington	1	3	1	1	2	2	..	..	..	..	..	3·11
West Coast	..	..	2	1	..	2	..	..	..	..	..	3·03
Westland	..	..	1	..	..	..	..	..	..	..	..	2·47
Otago-Southland	..	..	..	..	..	1	..	..	..	..	..	4·29
Ashburton - North Canterbury	..	..	..	..	..	1	..	..	..	..	..	4·12
Auckland-Waimarino	..	1	..	..	..	..	..	..	..	..	..	2·40
Total	5	19	16	24	19	22	10	5	7	2	1	..
North Island	4	11	3	4	4	6	5	3	2	1	..	..
South Island	1	8	13	20	15	16	5	2	5	1	1	..
Area 1	..	..	..	..	3	2	4	3	1	1	..	4·19
Area 2	5	15	9	10	5	6	1	..	1	..	..	2·82
Area 3	..	2	4	6	6	2	1	1	..	..	..	3·61
Area 4	..	2	3	8	5	12	4	1	5	1	1	4·23

typical waters for which adequate amounts of data were available. The results are shown in Figs. 14 and 15. In the panel for each water the upper number is the number of recorded days in the distribution and the lower the mean length of day. The data on which the figures are based are those obtained for the 1950–51 and 1951–52 seasons. The shape of the curve varies greatly for different waters. For the waters in Fig. 15, where the mean is 3 hours or less, the curve has a strong peak at about 2 hours and falls away more or less rapidly above this figure. In Fig. 14, where the mean is more than 4 hours the curve tends to have a fairly flat top extending from about 2 to 6 or 7 hours; there is sometimes a suggestion of bimodality. The appearance of the curves suggests that they may be interpreted by assuming that an angler normally fishes for either a half-day or a whole day. The half-day is less than 4 hours and is most usually about 2 hours; the whole day is more than 4 hours and has the peak of its distribution at 6 or 7 hours. In the waters with a low mean length of day half-days predominate, while in the waters with a greater mean half-days and whole days occur approximately equally. This is shown by Table 28 which gives the percentages of whole days and half-days recorded in each of the waters shown in the figures; half-days are taken to be all fishing days of 4 hours or less.

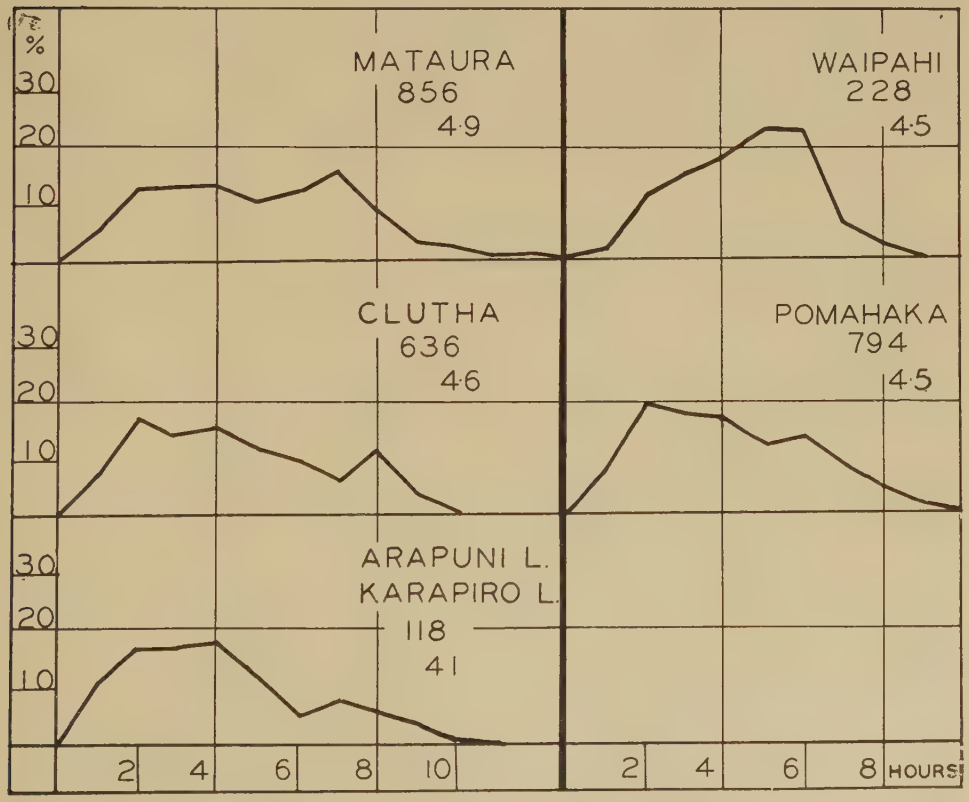


Fig. 14: The distribution of the length of the recorded fishing day for five waters in which the average day was over 4 hours. Results for the 1950–51 and 1951–52 seasons.

Table 28. The Percentage Distribution of the Recorded Days for the Waters in Figs. 14 and 15 Between Half-days of Four Hours or Less and Whole Days of More Than Four Hours

	Half-days	Whole Days
Mataura	44·7	55·3
Waipahi	45·7	54·3
Clutha	54·2	45·8
Pomahaka	60·8	39·2
Arapuni-Karapiro	62·9	37·1
Mangatainoka	74·3	25·7
Motueka	87·3	12·7
Mangawhero	88·9	11·1
Tukituki	90·2	9·8

The similarity between the various waters in the same area and the differences between different areas suggest that there are differences in the habits of anglers in those areas. The data so far considered are drawn from the records of a large number of anglers for each water, and the differences described could arise either if the majority of anglers in each area followed the characteristic habits of that area, or if the proportion of anglers behaving in a particular way, e.g., fishing mainly half-days, or mainly whole days, changed from area to area. To investigate this point it is necessary to examine the distribution of length of days in records of large numbers of days fished by single anglers preferably on one water. Few anglers have contributed sufficient data but the records of a group of seven anglers, from diverse districts, which have already been used to study the distribution of bag size (Allen, 1955), are also suitable for this purpose. The distributions obtained from

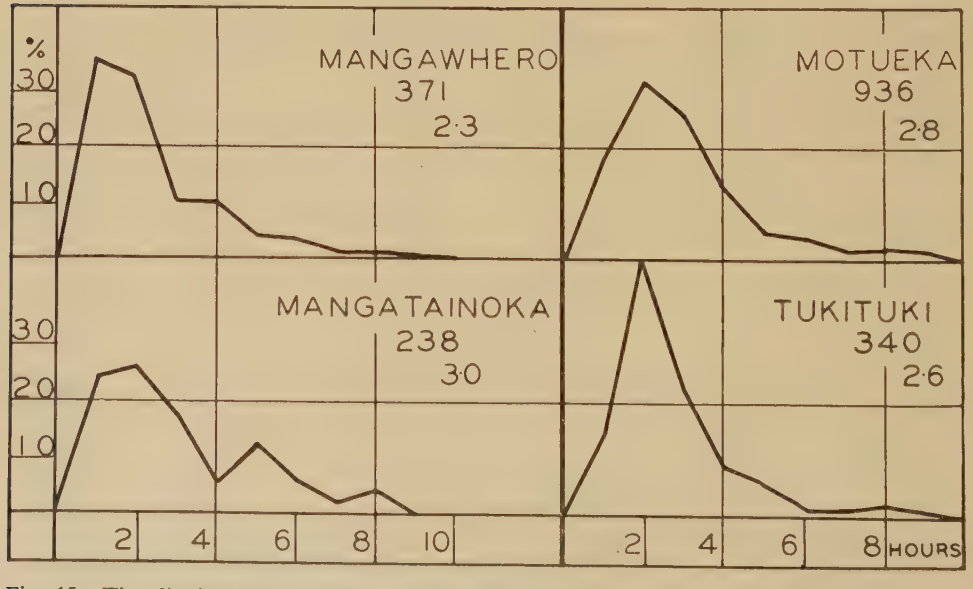


Fig. 15: The distribution of the length of the recorded fishing day for four waters in which the average day was less than 4 hours. Results for the 1950–51 and 1951–52 seasons.

these anglers are plotted in Fig. 16. Comparison of this and the two previous figures shows a remarkable degree of similarity between the individual distributions and the general curves for all anglers on the same waters. As a necessary corollary of this, the curves for two different individuals fishing the same water resemble one another. These results seem to indicate that for each district and to some extent for each water a characteristic pattern of behaviour develops which is adhered to by a large proportion of the anglers concerned. The apparent resemblance is increased to some extent by the fact that the data for the water include those for the individual anglers. In all cases, however, only a small proportion (usually 15 per cent or less) of the total is derived from the individuals who are included in Fig. 16, and there is therefore a real similarity between the general and individual distributions.

The tendency of anglers in one district to show similar distributions in length of fishing day does not, however, outweigh the variation which naturally occurs between individuals. This is shown by the F test (Snedecor, 1946), which has been applied to two of the larger series of data, those for Nelson and Otago in the 1948–49 season. With 44 and 84 anglers respectively, these give values of F of 7·2 and 19·2, which are very greatly in excess of the 1 per cent significance level.

For the same series, tests of the difference between waters also give significant results, although the values of F are much less than those for differences between anglers. Since each angler does not distribute his effort evenly over all the waters but usually concentrates on a very few rivers, there must be a high degree of interaction between the differences between anglers and those between waters. The nature of the data, and particularly the large proportion of blanks in a two-way table of anglers and waters, makes a full analysis of variance very complex, and it has not therefore been considered worth while to extract the interaction and to assess separately the true variance due to anglers and to rivers.

In using the data derived from a relatively few anglers to assess the total angling effort, it is necessary to consider whether the diarists are representative of the whole angling population. It has been shown earlier in this section that there is evidence that the diarists tend to fish on more days per season than do most anglers, and it is desirable to find out whether there are similar tendencies in regard to length of the fishing day. Since diaries are more commonly kept by those anglers who fish frequently, any correlation between diary keeping and length of fishing day is most likely to arise from a correlation between length of day and number of days fished in a season. The data are suitable for testing this correlation directly. Owing to the variation from district to district both in length of day and number of days fished, it is desirable to apply the test independently to separate districts. The results for the two districts yielding the largest amounts of data are summarised for the 1948–49 and 1949–50 seasons in Table 29. The Nelson results show an increase in the length of fishing day with number of days fished, but those for Otago vary quite irregularly. Statistical analysis of correlation for the Nelson data gives a value of r which, for the 1948–49 results, is significant at the 5 per cent level, but is well below significance for the 1949–50 results. Thus there is little indication that the length of the fishing day is usually affected by the number of days fished in the season, and it is probably therefore justifiable to assume that the diarists are reasonably representative of anglers as a whole in this respect.

The data have shown that, as was to be expected, there are great differences between individual anglers in the length of their normal fishing day; they have also shown that there are smaller but significant differences between various waters in

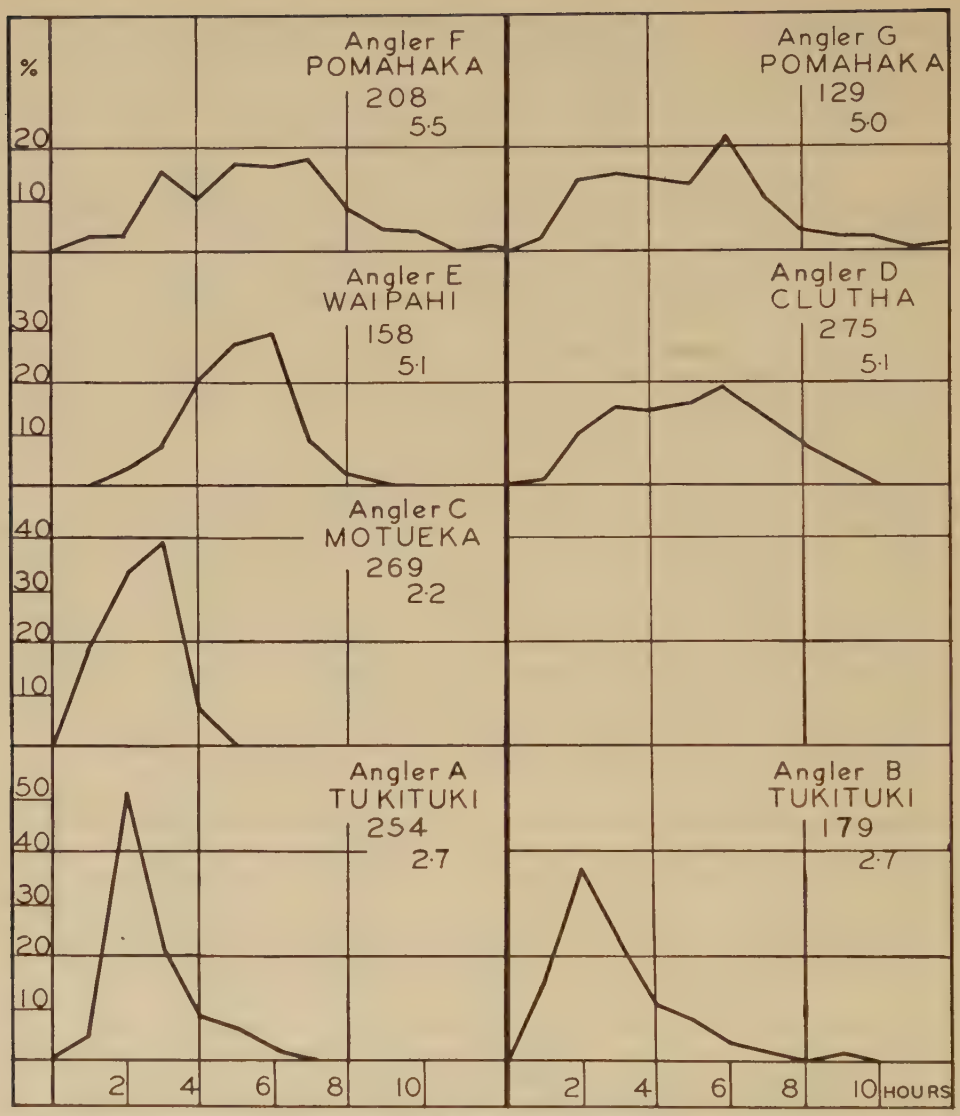


Fig. 16: The distribution of the length of the recorded fishing days on one water by seven individual anglers.

Table 29. The Relation Between Number of Days Fished in the Season and Mean Length of Fishing Day for the Nelson and Otago Districts in the 1948–49 and 1949–50 Seasons

Number of Days Fished	Nelson			Otago		
	Anglers	Days	Mean Hours Per Day	Anglers	Days	Mean Hours Per Day
1–10	22	171	2·89	19	101	4·16
11–20	36	535	2·72	46	717	4·82
21–30	9	214	3·27	37	957	5·22
31–40	11	380	3·32	21	755	3·91
41–50	5	238	3·56	13	601	4·43
51–60	4	231	2·37	16	1,021	4·49

this respect. The length of fishing day depends primarily upon the behaviour of the human beings concerned, and the difference between waters must therefore arise from the influence on that behaviour of certain attributes of the waters. A full analysis to determine the nature of these attributes and their method of operation would be laborious and would require far more comprehensive data than are at present available. A preliminary study has, however, been made of a few of the factors which may be involved. The distance which an angler has travelled might have some effect on the length of his fishing day, although two opposing influences might be involved. On the one hand there might be a tendency for the time spent fishing to increase with the distance travelled, owing a feeling that it was not worth while travelling a long distance except for a substantial day's fishing. On the other hand, the time spent travelling cuts into that available for fishing, and this might produce a tendency for the length of day to vary inversely with distance travelled.

The estimates of distance travelled which have been used in this analysis are based on the single, not return, journey by the most direct route from the centre where the angler lived to the nearest point on the water that he fished. It is assumed that each fishing day was a separate excursion. In the analysis distances are grouped in units of 10 or 20 miles, which will smooth out most of the minor errors arising from these assumptions.

The length of day has been compared with the distance travelled for the Nelson district in the 1949–50 and 1950–51 seasons and for the Otago district in the 1949–50 season. The results are summarised in Table 30. The Nelson results show a steady increase in length of day with distance travelled, but the Otago results are less simple. The length of day is shortest for the least distance, but there is a very

Table 30. The Effect of Distance Travelled on Mean Length of Fishing Day (Results for Nelson for the 1949–50 and 1950–51 Seasons and for Otago for the 1949–50 Season.)

Distance Travelled (Miles)	Nelson		Otago	
	Number of Days	Mean Number of Hours Per Day	Number of Days	Mean Number of Hours Per Day
1–10	581	2·45	872	4·04
11–20	134	2·53	277	5·78
21–40	343	2·93	278	5·82
41–60	158	3·15	84	4·83
61–	247	3·37	219	4·16

Fig. 17: The Otago Acclimatisation District showing residential areas 1 and 2 used in the analysis of the effect of distance travelled on length of fishing day.

abrupt rise at about 10 miles, and between 10 and 40 miles the length of day is almost constant. At distances greater than 40 miles there is a definite decrease. The greater complexity in Otago is not unexpected, since the district is not only larger in extent but also contains a much greater number and diversity of types of fishing waters. In order to break down the complexity slightly, the Otago anglers have been divided into geographical groups according to the location of their homes. The basis of this division is shown in Fig. 17. The groups selected for separate analysis are those resident in Areas 1 and 2. Area 1 is the urban district centred on Dunedin and including the townships of Port Chalmers and Mosgiel. Area 2 is a fairly closely settled agricultural district and is well supplied with a network of good trout streams belonging mainly to the Clutha and Mataura systems but including also a number of independent coastal streams. The results from these two areas are compared in Table 31. The most striking difference is in the distances normally travelled by the two groups. The anglers of Area 1 living in an urban district and with few fishing waters close at hand are accustomed to travel considerable distances for their fishing; only 29·0 per cent of recorded days were spent within 20 miles of home, and almost a third more than 60 miles away. Those from Area 2 have good fishing waters within easy reach almost anywhere in the area and as a result they rarely travel more than a short distance; 90·3 per cent of the recorded days were spent within 20 miles, and none of the anglers in this area ever travelled more than 60 miles.

Table 31. The Number of Days Fished and Mean Length of Day in Relation to Distance Travelled for Anglers Resident in the Two Areas of the Otago Acclimatisation District Marked in Fig. 17

	Area 1			Area 2		
Number of anglers ..	24			24		
Distance Travelled (Miles)	Number of Days	Percentage of Days	Mean Number of Hours Per Day	Number of Days	Percentage of Days	Mean Number of Hours Per Day
1–10	58	10·4	4·13	724	76·6	4·14
11–20	104	18·6	7·45	126	13·7	4·78
21–40	182	32·6	5·97	70	7·4	5·21
41–60	37	6·6	6·03	24	2·5	6·84
61–	177	31·6	4·58	..	..	..

The relation between distance travelled and average length of day was also different in the two areas. In the rural Area 2 the length of day increased steadily with the distance travelled, as it did in Nelson, but to an even greater extent. The variation in the urban Area 1 has the same irregular form that was seen in the combined results for the whole Otago district. This is partly because of the great preponderance of Area 1 anglers among those who travelled the greatest distances. Analysis of the waters fished by Area 1 anglers at different distances from their homes throws some light on the rather irregular relation between distance and length of fishing day. The principal water within a radius of 10 miles is the Leith, which actually flows through Dunedin. In the region between 10 and 60 miles, the main waters are those of the Taieri system. The waters in the most distant region,

beyond 60 miles, are those of the Pomahaka subsystem of the Clutha, and beyond it the Mataura and its tributaries. The short average day on the Leith seems to be a direct reflection of the very short distance which Area 1 anglers have to travel to reach it, and it is identical with the average day of anglers travelling similar distances in Area 2. The difference between the lengths of day for distances of 10 to 60 miles and over 60 miles may be partly due to differences in customary fishing methods. The waters more than 60 miles from Area 1 are mainly fly-fishing streams. They are the waters which generally lie within 20 miles of the homes of anglers in Area 2, and Table 31 shows that the average fishing day on these waters is very similar for Area 1 and Area 2 anglers. On the other hand, in many of the waters of the Taieri system, which lie at an intermediate distance, fly is comparatively little used and minnow and worm are the lures chiefly employed. This is illustrated by Table 32, which shows the distribution of fishing days between methods, and the average length of fishing day for each, for the main Otago waters in the 1950–51 and 1951–52 seasons. The top three waters in the table are obviously minnow and worm waters. They lie at distances of 20 to 50 miles from Dunedin, the main population centre in Area 1. On the bottom three waters, which are representative of the principal fishing streams in Area 2 and which are 75 to 90 miles from Dunedin, fly fishing is clearly the favourite method. The table shows that there is a general tendency for the length of day to be less for fly fishing than for the other two methods, and this is particularly marked for the Clutha and the Taieri. Between the other two methods there is no consistent difference; in the first three waters the average day is longer for worm fishing, but in the last three, where fly fishing is the usual method, the day is slightly longer for minnow fishing.

Table 32. The Mean Length of the Fishing Day and the Percentage of Days Devoted to it for Each of the Main Fishing Methods in the Principal Otago Waters

	Number of Days	Mean Number of Hours Per Day			Percentage of Days		
		Fly	Minnow	Worm	Fly	Minnow	Worm
Taieri..	267	2·85	3·92	5·99	21·3	40·2	31·5
Mahinerangi-Waipori	191	7·03	6·26	7·54	6·3	46·1	41·8
Clutha	637	2·94	4·03	5·44	3·8	40·7	33·9
Pomahaka	773	3·87	4·43	4·05	60·3	22·7	11·5
Waipahi	218	4·37	6·36	4·44	84·8	3·2	8·2
Mataura	636	5·02	5·76	5·78	59·4	33·6	4·2

The data therefore indicate that the distance which an angler travels to fish has some effect on the length of time spent fishing; the length of the fishing day increases with the distance travelled. The method used also seems to exert a slight influence; the fly-fishing day for instance tends to be shorter than that devoted to the other methods. These effects do not, however, account for the major differences between districts in the usual length of the fishing day; Tables 29 and 30 show, for instance, that Nelson anglers fish a consistently shorter day than Otago anglers, whatever the number of days fished in the season, or however far they have travelled. The length of the fishing day seems to depend primarily on intangible factors and the locally established custom appears to play an important part. There is no indication at either the individual or the district level of any correlation between the usual length of the fishing day and the number of days fished during the season.

2. THE TOTAL DISTRICT EFFORT

SUMMARY

From the estimates of average individual fishing effort and the known number of licence holders the total effort for each district can be estimated (Appendix 4). It ranges from nil up to about 200,000 hours per season in Otago. When the widely varying areas of districts are allowed for, the effort is generally between about 1 and 30 hours per square mile per season in districts providing any significant amount of angling. Intensity is greatest in the south-east of the South Island and in the centre of the North Island. It is light in the extreme north and west of the South Island, and negligible in the northern extremities of the North Island.

Population density has some influence on angling intensity, although the intensity is greater in the South Island despite a generally lower population density. Within the South Island the distributions of population and angling intensity are roughly similar. In the North Island, the highest intensity occurs in the Taupo-Rotorua area where population density is very light, but there is a great influx of visiting anglers. The lowest intensity is found in the virtually troutless north, although the population is relatively dense. Apart from these extremes there is a general similarity in the two distributions.

The proportion of anglers in the population as measured by the percentage of licence holders among males of 18 years and over has considerable influence on angling intensity. The percentage varies from about 1 to 10 in districts having significant amounts of angling. Except for the tourist areas it is highest in the south and east of the South Island, and shows a general tendency to decrease northwards.

Comparison with the distribution of rate of catch both in numbers and weight of fish shows that the proportion of anglers in the population tends to be correlated with the quality of angling. The relationship, however, is not complete, and a notable exception occurs in the north-west extremity of the South Island, where the proportion of anglers is much smaller than the quality of angling would warrant. Accessibility of fishing water also seems to have some influence.

The Government-controlled districts – Rotorua, Taupo, and Southern Lakes – are essentially tourist areas and make a contribution to the total amount of angling in New Zealand out of all proportion to their size. In Taupo, the extreme case, the amount of angling is four times as great as it would be if all residents were anglers and there were no visitors. In the North Island, three-quarters of the total amount of angling is done in Taupo and Rotorua, mainly by visiting anglers. In the South Island the corresponding figure for the Southern Lakes district is only 6 per cent. The total amount of angling in the South Island (660,000 hours per season) is only three-quarters of that in the North Island, but per head of population the amount in the South Island is nearly 50 per cent greater than that in the North Island.

The average individual fishing effort in a season provides a basis for the estimation of the total effort in each district. The estimates obtained in this way for each acclimatisation district are shown in Appendix 4. This is divided into three sections according to the sources of data available for the various districts. In the top section are those districts for which diary data were directly available. The middle section contains those districts controlled by acclimatisation societies which did not co-operate in the diary scheme; the estimates of average individual effort used for these are generalised averages taken from similar areas in the upper part of the table. The bottom section comprises the three districts controlled by the Department of Internal Affairs; different methods of data collecting were used here, and most of the results obtained will be reported elsewhere. In the first two sections of the table estimates are based entirely on the holders of men's whole-season licences. Women, children, and holders of short-term (half-season, monthly, weekly, and daily) licences are ignored. Not only are whole-season licences much more numerous than the other classes, but all available evidence suggests that the average amount of fishing and number of fish caught per season by women and children and by holders of short-term licences are very much less than for men. In 1951–52, 14,794 out of the 21,418 whole-season licences issued by all acclimatisation societies were sold to men; of the remainder 5,061 were for children under 16. By contrast only 2,810 short-term licences were sold, over half of them being for a week or less. The estimates of total effort will therefore have a low bias but only to the extent of a few per cent.

Column 1 of Appendix 4 shows the estimated mean number of days fished by the individual angler in each district. The figures marked with a cross are taken from the regression equations in Appendix 2 (b). As discussed earlier, they therefore represent the highest standard of accuracy available. For the other districts in the top section of the table the figures are those given in Table 22 reduced by one-third as an approximate correction for the bias produced by the tendency of diarists to fish on more than the average number of days per season.

Column 2 shows for each district the average length of fishing day taken from Table 27. Since no evidence has been found that this is subject to systematic bias, these figures are unmodified. Column 3 contains the estimated number of hours fished per season obtained by multiplying columns 1 and 2. For the second section of the table this column has been completed by inserting estimates of 40 hours and 60 hours for the North Island and South Island districts respectively since these seemed to be typical values. Column 4 shows the number of holders of men's whole-season licences for the 1951–52 season taken from Table 1 and p. 11. From columns 3 and 4 are obtained by multiplication the estimates of the total number of hours fished in each district for the 1951–52 season, and these are shown in column 5. Strictly, these figures are estimates of the number of hours fished by the licence holders of the district but, since the amount of interchange between districts is generally small and partly balanced out by reciprocal movements, they provide a satisfactory estimate of the amount of fishing within the districts. The only important exception to this is provided by the Internal Affairs districts, which receive large numbers of visiting anglers. Since licences issued by acclimatisation societies are not valid in these districts, although freely interchangeable between societies, the estimates given in the first two sections of the table are not affected by anglers visiting the Internal Affairs districts. The estimates for the latter districts will be discussed later.

The appendix shows that there is a great variation in the amount of fishing in the various districts. It ranges from a few hundred hours for the whole four districts in the North Auckland peninsula up to nearly 200,000 hours in Otago. The districts, however, vary greatly in such features as area, population, and amount and quality of angling available. As a first step in the analysis of the distribution of the angling effort, the influence of varying areas has been eliminated by calculating the hours of fishing per square mile for each district. Column 6 shows the approximate area of each district and column 7 shows the fishing intensity in hours per square mile obtained by dividing column 6 into column 5. The range of fishing intensity is still considerable although much less than that for total effort. For the society-controlled districts it ranges from zero in North Auckland to over 20 in Otago, South Canterbury, and Southland. The distribution is shown by main categories in Fig. 18. It is evident that the greatest fishing intensity occurs on the east coast of the South Island, particularly in the southern half; the west coast of the island and the northern tip are relatively lightly fished. In the North Island intensity is generally moderate except in the northern extremities where it is negligible; a very high intensity occurs locally at the centre of the island in the Government-controlled Taupo and Rotorua districts.

The distribution of population may be expected to have an influence on angling pressure. Column 8 therefore shows for each district the size of that portion of the population which is concerned in this study, i.e., males of 18 years and over. The figures are taken from the results of the 1951 census and are therefore closely comparable with the data for the 1951–52 angling season. A few minor approximations were made in determining district populations, but it is unlikely that the errors they produced amounted to more than 50 for any district and they are therefore negligible. In column 9 the population density in males, 18 and over, per square mile is derived from columns 6 and 8. The distribution is shown in Fig. 19. Comparison with Fig. 18 shows some striking differences, particularly between the North and South Islands as a whole. The South Island has a much less dense population, although fishing intensity is greater. In the North Island, fishing intensity is generally light despite the much denser population. Within the South Island there is some general agreement between fishing intensity and population distribution. In particular, both are highest along the east coast although population density is heaviest at the northern end of this strip while fishing intensity is heaviest at the southern end. In the North Island the position is complicated by the lightly populated, heavily fished Government-controlled areas of Taupo and Rotorua but apart from this there is a general similarity between the distribution of population and fishing intensity.

The discrepancies between the distributions of fishing intensity and population are sufficient to show that other factors are involved. Interest in angling may be assessed by the proportion of the population which take out whole-season licences. This is shown as a percentage in column 10 and graphically in Fig. 20. The general appearance of this figure is similar to that of Fig. 18. For example, the proportion of men taking out fishing licences is greater on the east coast of the South Island than in any other part of the country except the Government-controlled districts, and it is this which accounts for the high fishing intensity in the area. It appears, therefore, that the extent of popular interest in fishing is a primary factor, of even greater importance than density of population, in determining the fishing intensity in an area. Since it seemed likely that interest in angling would reflect to some

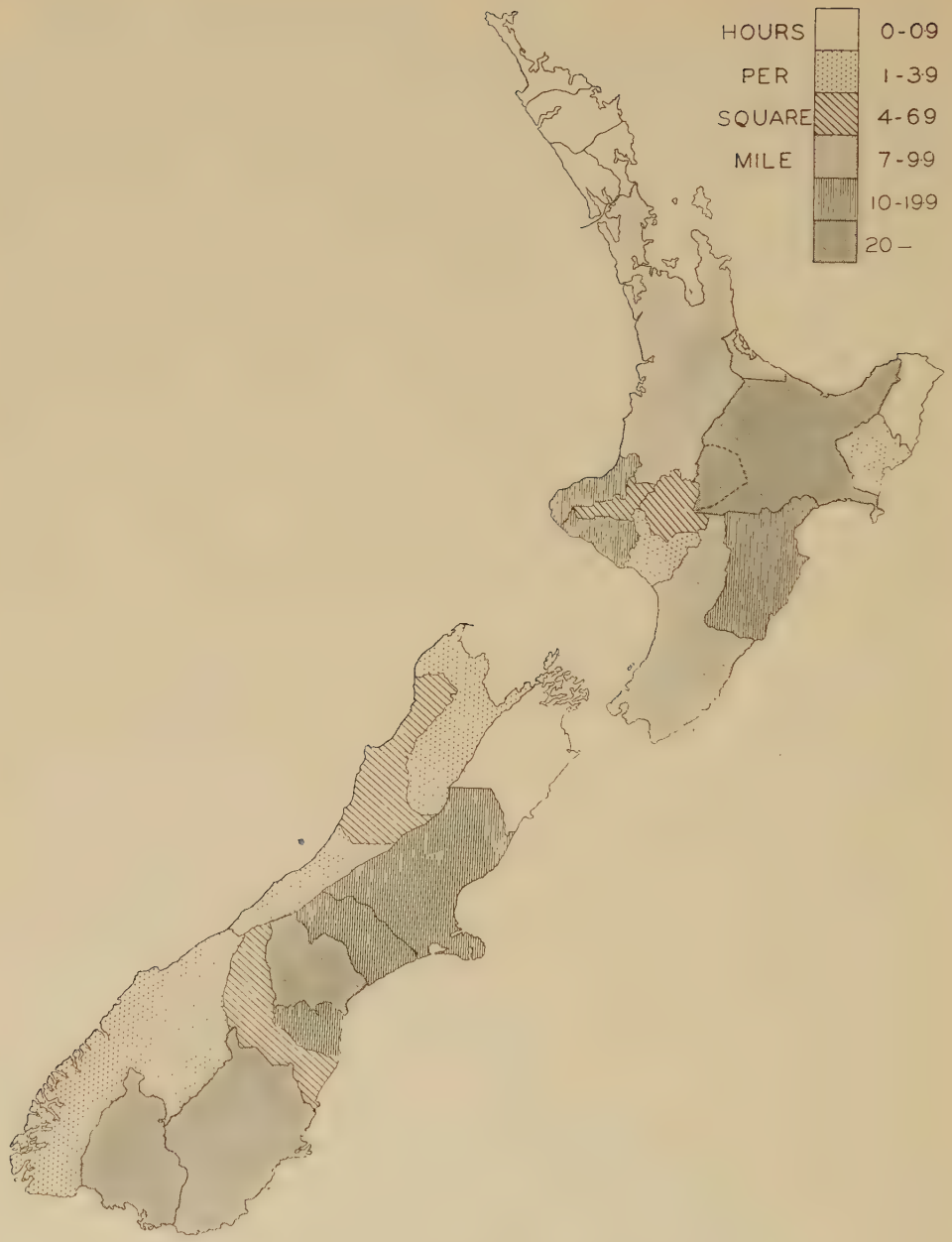


Fig. 18: The distribution by acclimatisation districts of fishing pressure in hours per square mile.

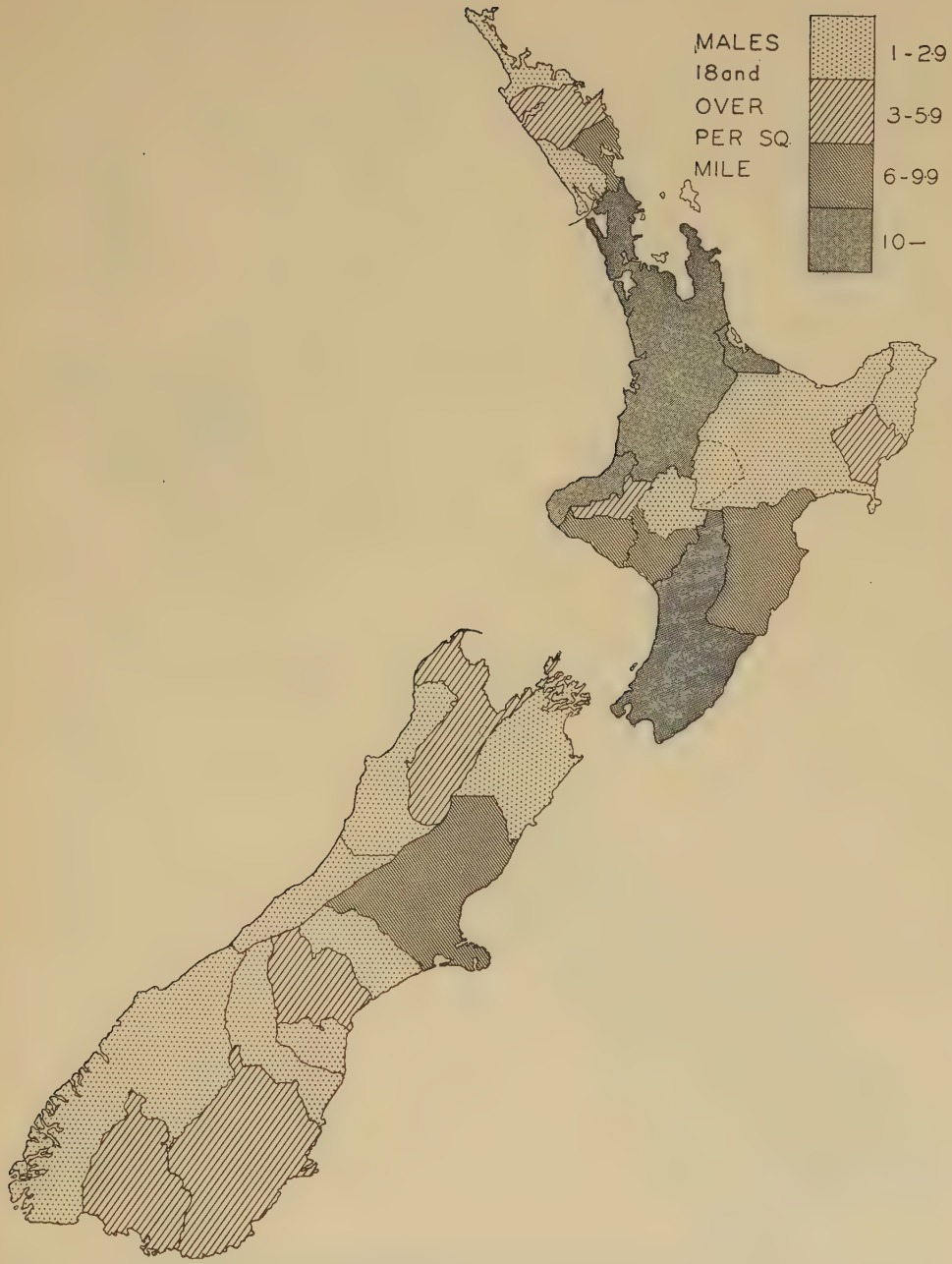


Fig. 19: The distribution by acclimatisation districts of population density in males of 18 years and over per square mile.

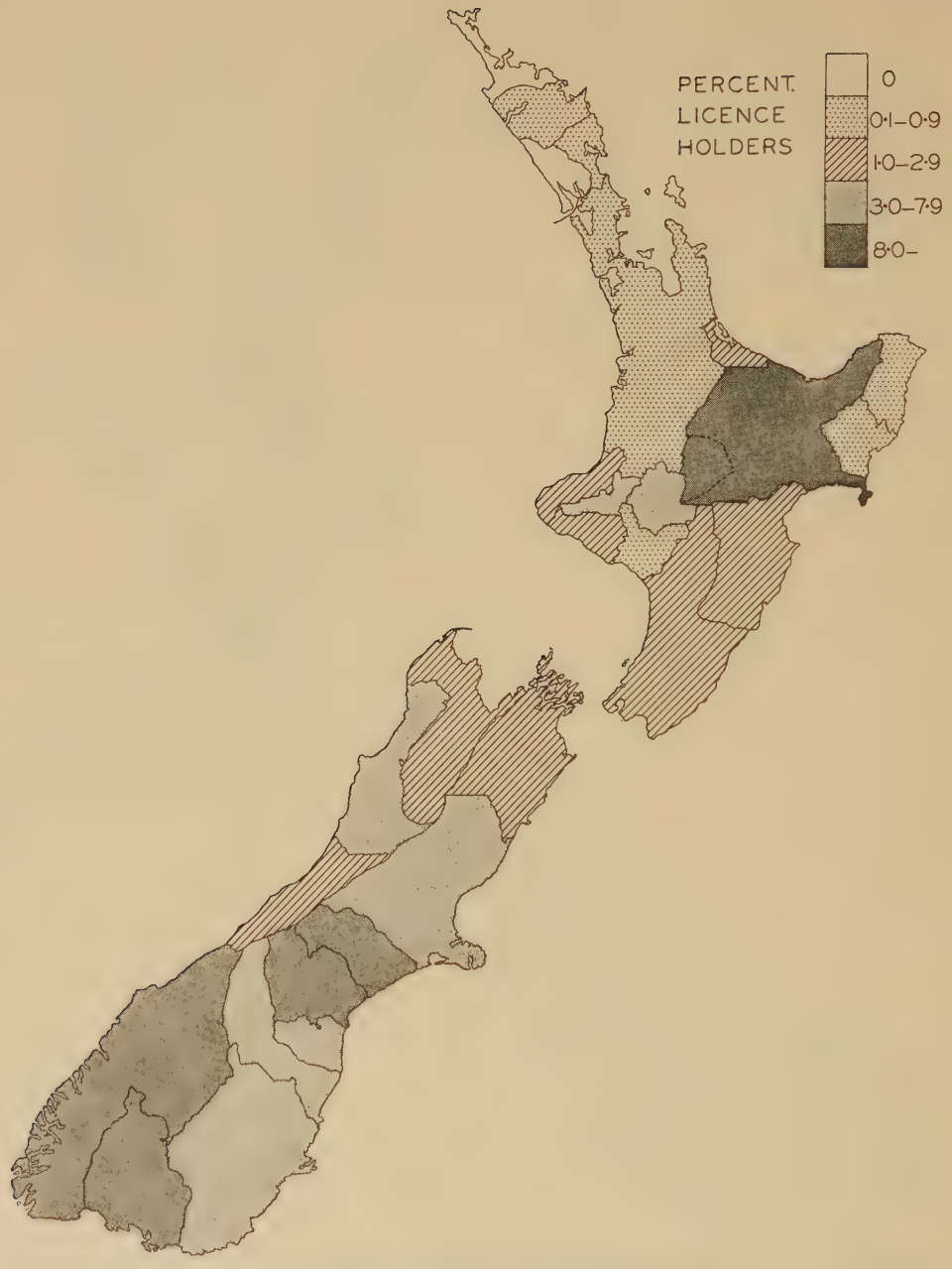


Fig. 20: The distribution by acclimatisation districts of the percentage of whole-season licence holders in the adult male population.

Fig. 21: The distribution by acclimatisation districts of the mean rate of catch in fish per hour.

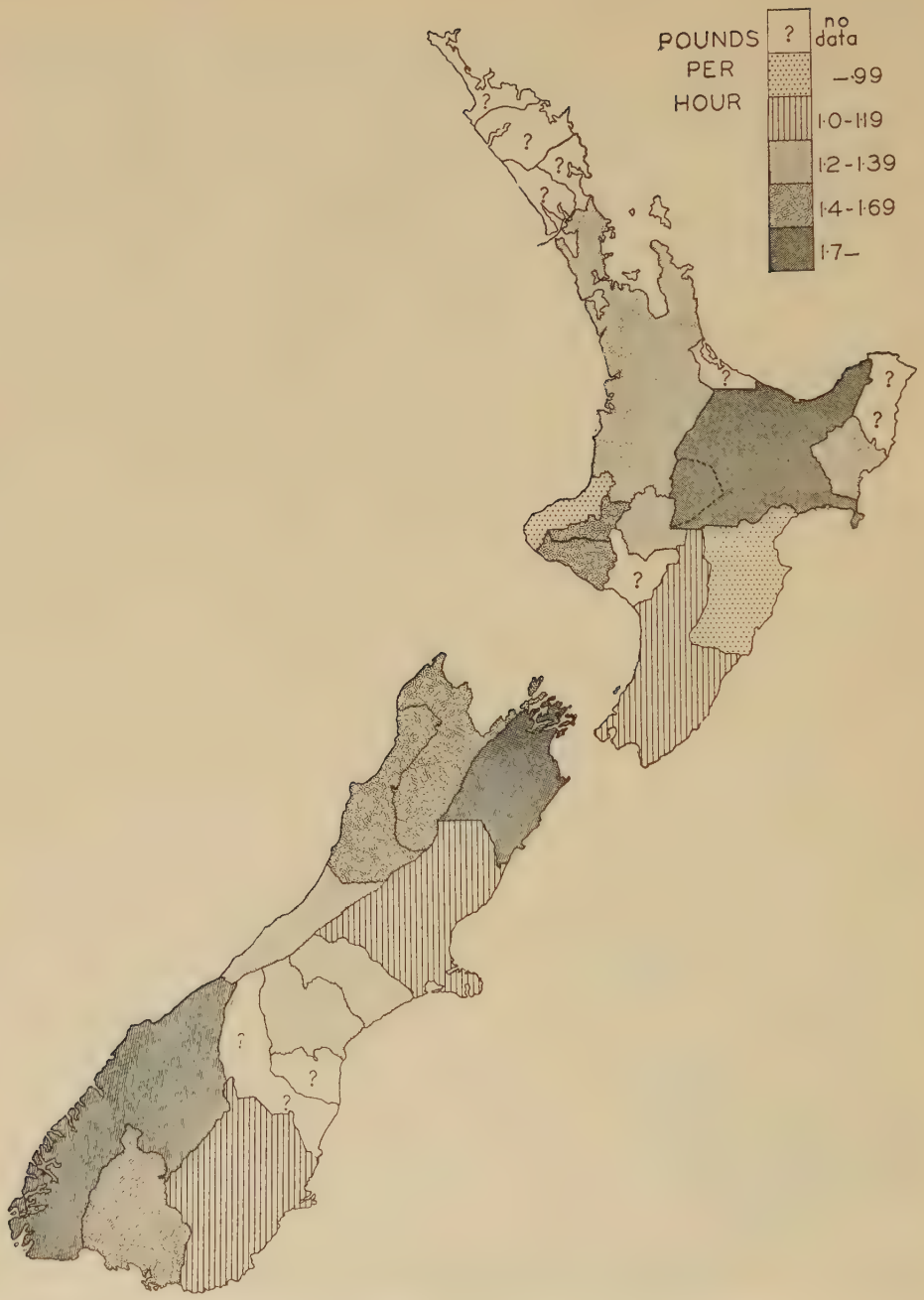


Fig. 22: The distribution by acclimatisation districts of the mean weight of fish caught per hour.

extent the quality of fishing available, the table also shows in column 11 the average rate of catch for each district. The figure given is an overall average based on all available diary data for each district; the results for the different waters within the district are therefore weighted in accordance with the amount of data obtained from them and therefore very roughly in accordance with the amount of fishing they yield. The results are also shown on the map in Fig. 21. Comparison with Fig. 20 shows some points of similarity in the distribution of rate of catch and proportion of licence holders. In particular the areas of high interest in fishing in southern Canterbury and in Southland have also very high average rates of catch. On the other hand the proportion of licence holders is unexpectedly low in the Nelson and Marlborough areas at the northern extremity of the South Island. In the North Island there is little agreement between the two distributions although the position is complicated by the large number of licences taken out in the Rotorua and Taupo districts, where the numerical rate of catch is relatively low. An alternative measure of fishing quality is given by the weight of fish caught per hour. An average weight for an individual fish has been determined from the mean weights of all the fish recorded as measured in Appendix 1. Weights have been estimated from lengths by assuming a condition factor of 110 on the cm.-gm. scale for all fish. In determining mean weights for each district in this way, the waters which did not yield enough data to warrant their inclusion in the appendix have been ignored, but it is not considered that this would significantly affect the results. These are shown in column 12, and by multiplying these figures by the mean number of fish per hour a mean weight per hour is obtained and shown in column 13 and Fig. 22.

In general, the distribution of rate of catch by weight shows less agreement with that for proportion of licence holders than does the numerical rate of catch. The very high proportion of licence holders in Government-controlled districts in both islands is, however, seen to coincide with very high weights of catch per hour.

Another factor which probably contributes substantially to the proportion of anglers in the population is the amount of reasonably good fishing water within convenient reach. This cannot be easily expressed in numerical form but it varies considerably from district to district. Some areas, such as parts of Southland, Otago, and South Canterbury, are covered with a close network of streams, nearly all containing abundant trout and easily accessible by road. In others, such as Marlborough, the northern part of North Canterbury, and northern Hawke's Bay, many of the major rivers are in mountainous country and difficult of access. In other districts again the rivers, although numerous and easy of access, contain few trout; this applies for instance, not only to the four North Auckland districts but also to much of the northern part of the Auckland district.

Thus the factors determining the fishing pressure in any district include the density of population, the quality of fishing available, and the amount of useful and accessible fishing water. Other factors probably also operate, including intangible ones such as social customs. The big differences which occur from district to district in such effects as length of fishing day indicate the reality of these behaviour differences.

It is necessary to give special discussion in this section to the Government-controlled districts, Rotorua and Taupo in the North Island, and Southern Lakes in the South Island. As has been explained earlier, different arrangements were made for the collection of angling statistics from these areas and the results will be

reported elsewhere. These districts, however, play such an important part in the general distribution of fishing pressure, particularly in the North Island, that it would be unrealistic to ignore them in the present section. They have therefore been included in Appendix 4 and Figs. 18–22; the figures in columns 3–5 of the appendix have been derived from data provided by the Department of Internal Affairs.

As the table shows, these districts have small resident populations, but they provide a large amount of angling of high quality. They are also areas possessing considerable scenic attractions. They are therefore fished largely by visiting anglers and to a relatively small extent by local residents. For the 1951–52 period approximate estimates of the percentage of total fishing effort derived from visiting anglers in the three districts are: Rotorua 60 per cent, Taupo 87 per cent, Southern Lakes 80 per cent. Because of the short time which visitors usually spend in these districts, many of them only take out short-term licences (i.e., monthly, weekly, weekend, or daily), and it has therefore been necessary to estimate the effort contributed to the total by these classes of anglers. Good data are available for the Taupo district regarding the average total hours fished by holders of the various classes of licences, and less good but still useful data are available for the other two districts. From these figures, combined with the total numbers sold of the various classes of licences, the estimates of total fishing effort given in Column 5 have been calculated. The numbers of licences shown in Column 4 for these districts are obtained by dividing the total effort by the average number of hours fished by whole-season licence holders. They are not therefore the actual numbers of whole-season licences but the numbers which would have been sold to produce the same effort if virtually all fishing were done by such licence holders as in other districts. The actual numbers of whole-season licences sold were much smaller: Rotorua 3,754, Taupo 1,943, Southern Lakes 647. The percentages of licence holders shown in column 10 are derived from the hypothetical figures; the large number of visitors is responsible for the very high apparent percentages. In Taupo, for instance, the amount of fishing is nearly four times as great as would be expected if every resident man was an angler and there were no visitors. The actual percentages of residents taking out whole-season licences are approximately: Rotorua 16 per cent, Taupo 55 per cent, Southern Lakes 12 per cent. They are thus much higher than in any other district, particularly in Taupo.

These three Government-controlled districts clearly make a substantial contribution to the amount of fishing available, particularly in the North Island. The position in each island is summarised in Table 33. In the North Island the Government-controlled districts are receiving over three-quarters of the fishing effort, but in the South Island only about 6 per cent. On the basis of population, the society districts provide only one-sixth as much fishing in the North Island as in the South Island, but, as a result of the contribution of Rotorua and Taupo, the North Island as a whole provides two-thirds as much as the South Island. It would be necessary to provide another 400,000 hours of fishing in the North Island to give the same amount of fishing per head as in the South Island. Even to maintain the present position the majority of North Island anglers have to travel to other districts to fish, while those in the South Island can satisfy their needs in their home territory. Cunningham *et al.* (1953) have provided data on the districts of origin of Rotorua and Taupo anglers. They have shown that the majority of visitors to Rotorua come

from the Auckland district and of those to Taupo from Wellington and Hawke's Bay.

Table 33. The Total Fishing Effort, and the Average Amount Per Head of Population for Society- and Government-controlled Districts for the North and South Islands Separately and for New Zealand as a Whole

		Hours Fished (× 1,000)	Population Males, 18 and Over (× 1,000)	Hours Per Man
North Island ..	Society districts	212·4	410·0	0·52
	Government districts	676·4	11·6	58·31
	Total	888·8	421·6	2·11
South Island ..	Society districts	620·6	205·7	3·02
	Government districts	39·9	2·0	19·95
	Total	660·5	207·7	3·18
Combined ..	Society districts	833·0	615·7	1·35
	Government districts	716·3	13·6	52·66
	Total	1,549·3	629·3	2·46

3. DISTRIBUTION WITHIN DISTRICTS

SUMMARY

In each district the estimated total effort has been allocated between the various waters in the same proportions as were found in the recorded effort. In this way an approximate detailed distribution of effort has been worked out. The resulting map is shown in Fig. 23. The accuracy of the estimate varies greatly between districts, being highest where diary coverage was best.

In the previous section, estimates have been made of the total angling effort exerted in each acclimatisation district during the 1951–52 season. This is easier to estimate than the effort expended on any particular water since the total number of anglers taking out a licence in each district is known accurately, but there are few reliable data on the numbers who fish each water, and the proportion of total fishing time spent there will vary greatly from angler to angler. The best method of estimating the total effort exerted on each water is therefore to take the estimated total effort for the district and to attempt to split it up between the various waters concerned. Where diaries were kept by a reasonably large proportion of anglers well scattered through the district, the distribution of the recorded effort will provide a reasonably good measure of the distribution of the actual effort. In districts such as Nelson, Otago, and Waimarino, the angling effort devoted to each of the principal waters can be estimated fairly accurately in this way. In districts yielding smaller numbers of diaries the estimated distribution of angling is correspondingly less accurate, and where few or no diaries are available the total effort can be distributed over waters only by an intelligent guess based on general knowledge of the area.

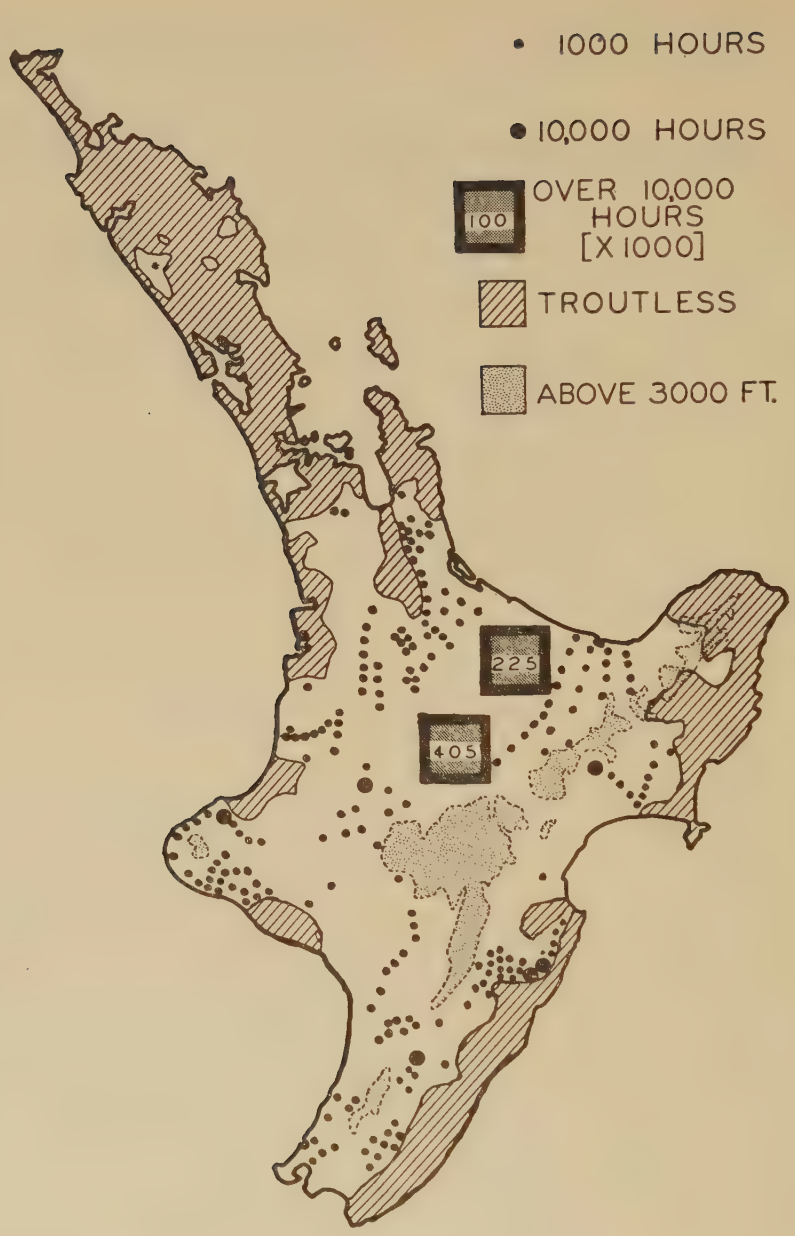

1000 HOURS
10,000 HOURS
100
OVER 10,000 HOURS [X 1000]
TROUTLESS
ABOVE 3000 FT.
225
405

Fig. 23: The approximate local distribution of angling effort throughout New Zealand. The shaded area represents land over 3,000 feet.

Table 34. The Total Number of Recorded Days Fishing Which Fell on Weekdays, and on Weekends and Public Holidays, in Each Month in the 1950–51 and 1951–52 Seasons. Also the Average Number of Diary-keeping Anglers Fishing on Each Category of Day

		October	November	December	January	February	March	April	Combined
Weekdays	Total	1,256	1,124	823	963	694	539	424	5,823
	Average	29·9	25·6	23·1	23·2	17·1	13·4	10·9	20·6
Holidays	Total	2,068	1,329	1,490	1,162	884	1,011	931	8,875
	Average	103·4	83·0	56·5	56·6	54·2	46·5	44·3	62·5
Combined	Total	3,324	2,453	2,313	2,125	1,578	1,550	1,355	14,698
	Average	53·6	40·9	37·3	34·3	27·7	25·0	22·6	34·6

In view of the highly variable reliability of the estimates it does not seem justifiable to attempt to tabulate the angling effort expended on individual waters. Estimates have, however, been made by the methods indicated, and they have been used in preparing the angling-distribution map shown in Fig. 23. On this diagram each small dot represents 1,000 hours of angling in 1951–52. On major rivers the appropriate number of dots are arranged roughly along the course of the rivers, but with only a slight attempt to place them according to the parts most often fished. On small streams and where the intensity of angling is less, the dots are placed in the general vicinity of the group of waters concerned.

As an indication of accessibility the map also shows approximately the main masses of high land over 3,000 feet in altitude. In the South Island fishing is obviously well distributed over nearly all the accessible country, although there is a general tendency for it to be most dense in the south-east part of the island. In the North Island the picture is rather different. Some of the main unfished areas are caused again by mountainous country, for instance, that between Taupo and Hawke's Bay. In other areas, however, e.g., Wellington east coast, Wanganui area, and North Auckland peninsula the lack of angling is due to the scarcity or absence of trout, as the figure also shows.

4. DISTRIBUTION THROUGH THE SEASON

SUMMARY

The average number of anglers fishing on any day declines steadily during the season except for a check over the January holiday period, when it remains steady. Fishing intensity is only about 40 per cent as great at the end as at the beginning of the season. The number of anglers is three to four times as great at weekends and public holidays as on weekdays. It is greatest of all on the opening day, whether this falls on a weekday or at a weekend. About 60 per cent of the total fishing days are at weekends and holidays. Bad weather may reduce the number of anglers to about one quarter of the normal for that day.

The length of the fishing day does not vary significantly during the season, but is about 50 per cent greater for weekends and holidays than for weekdays.

The number of anglers fishing on any one day in the season is not constant but varies greatly. The differences may be expected to be of two kinds; long term changes as the season progresses, and variations from day to day within a short period. The rapid variations will be due to two main causes: more anglers will be free to go fishing on weekends and public holidays than on weekdays, and there will be irregular variations due to weather and water conditions. The main subjects of the present study will be the long-term change as the season progresses and the comparison between working days and holidays. Only the data for the 1950–51 and 1951–52 seasons are in suitable form for this analysis.

Table 34 shows the combined results for both seasons and all districts. In this table, "holidays" includes weekends (i.e. Saturdays and Sundays), statutory holidays (i.e. Labour Day, Christmas Day, Boxing Day, New Year's Day, Good Friday, Easter Monday, Anzac Day, and the various provincial anniversary days), and certain days commonly taken as holidays (i.e. 27 December and 2 January), they

also include the usual opening day of the season (1 October) since so many anglers find an opportunity to fish on this day. In each section of the table the upper line shows the total number of recorded fishing days in each category for each month. Since the numbers of weekdays and holidays vary from month to month, the average number of diarists fishing on each type of day is shown in the lower line.

The table shows clearly that the variations in fishing intensity referred to at the beginning of this section are of considerable magnitude. There is an almost regular decrease as the season progresses. The average number of anglers fishing on any one day at the end of the season is only about 40 per cent as large as at the beginning. The decrease is slightly greater for weekdays than for holidays. The only break in the decrease is from December to January, when there is a slight increase for both weekdays and holidays. This is probably because a large number of anglers, like other sections of the population, take their annual holidays at this time and are therefore able to fish more frequently than usual. As a result of the decrease a large proportion of the total angling effort is expended in the early months of the season. About 40 per cent of the total recorded fishing days occurred in the first two months of the seven-month season.

A similar decrease in intensity of fishing was found for each acclimatisation district which provided an adequate amount of data. This general tendency probably arises from a progressive loss of interest in angling as the season continues; interest is restored during the close season when fishing is prohibited. It is probable that a different distribution of effort may occur in some waters in which fishing is better in a later part of the season or which lie in popular holiday areas remote from main centres of population. The general diary scheme has not provided sufficient data for any individual waters of this type to enable this effect to be studied. Hobbs (1953) has shown that in Lake Taupo and its tributaries, where both the above conditions apply, there are two main peaks of effort: one in January when the holiday season is at its height, and one in April when the fish are beginning to run into the tributaries.

Table 34 also shows that fishing intensity is generally three to four times as great on holidays as on working days. There are 71 holidays and 141 working days in a normal season not falling in leap year, but in the two seasons studied almost exactly 60 per cent of the recorded fishing days were on holidays, and only 40 per cent on working days, although there are twice as many working days as holidays in the fishing season.

The actual numbers of recorded days falling on each public holiday are shown in Table 35. Except for Anniversary Day, the days are arranged in chronological order. Anniversary Day falls on a variety of dates in the different provincial districts, and it is therefore relegated to the end of the table. The table shows again the tendency for the intensity of fishing, even on these special days, to fall off as the season advances. The high fishing intensity on the opening day is very noticeable. More anglers fish on this day than on any other, in spite of the fact that it is not a normal holiday. The difference between the numbers recorded on the opening day in the two seasons may have been caused by its occurrence in 1950–51 at a weekend (Sunday) and 1951–52 on a weekday (Monday). The order of the difference is approximately that of the intensity of a normal weekend day in the early part of the season.

There are two days in the table which show fishing intensities very much below the normal. These are Anzac Day in 1950–51 and Christmas Day in 1951–52. It

Table 35. The Number of Recorded Days Fishing on Each of the Public Holidays and Other Special Days in 1950–51 and 1951–52

	1950–51	1951–52	Total
1 October	209	161	370
Labour Day	104	76	180
Christmas Day	45	13	58
Boxing Day	65	62	127
27 December	48	48	96
New Year's Day ..	66	53	119
2 January	48	61	109
Good Friday	27	46	73
Easter Monday	54	47	101
Anzac Day	12	42	54
Anniversary Day ..	39	28	67

seemed possible that bad weather on these days was responsible for the small amount of angling, and information on weather conditions was therefore sought. Information provided by the New Zealand Meteorological Service shows that on each occasion the weather was dominated by a deep depression lying off the Otago coast, and that cold stormy weather with rain or showers prevailed in most parts of the country.

It seems likely that these conditions were responsible for the small amount of angling recorded on these days. This suggests that bad weather may reduce the amount of angling to as little as a quarter of the normal for a similar day.

The foregoing discussion has dealt only with the distribution of fishing days, but a complete study of fishing effort must also take into account variation in the length of the fishing day. The 1951–52 data have been analysed in respect to this. The changes as the season progresses are quite irregular and vary from district to district. They are probably chance effects arising from the changes in the amount of data from different individuals and from different waters. On the other hand, there is a consistent difference between working days and holidays. These results are summarised in Table 36 for seven of the principal districts and for all districts combined. The length of fishing day is considerably greater on holidays than on working days. For all districts combined it is about half as long again, and the ratio varies between 1·6 : 1 and 1·1 : 1 for different districts. When this effect is taken into account the proportion of the total fishing effort expended on holidays rises from about 60 per cent to about 70 per cent.

The occurrence of the opening day on a weekday and on a weekend in the two seasons studied provides an opportunity to examine the effect of this difference on the length of time fished. The mean number of hours fished on the opening day in each season is therefore included in Table 36. Two main tendencies can be observed: the time fished on the opening day is longer than on a typical day in the same category, and it was greater in 1950–51 when the day fell at a weekend than in 1951–52 when it occurred on Monday. In the second case, the length of day is about the same as on a typical holiday.

Rather similar tendencies for fishing to be concentrated on weekends and holidays and at the early part of the season have been recorded by Cooper (1953) and Rupp (1955). On Pigeon River, Michigan, Cooper found that more anglers visited

Table 36. The Mean Length of the Fishing Day for Weekdays and Holidays in 1950–51 and for the Opening Day in 1950–51 and in 1951–52. Results for Seven Principal Districts and for All Districts Combined

	Weekdays		Holidays		Opening Day, 1951–52		Opening Day, 1950–51	
	Number of Days	Mean Hours	Number of Days	Mean Hours	Number of Days	Mean Hours	Number of Days	Mean Hours
Auckland	175	3·34	310	4·74	7	5·29	16	5·84
Nelson	425	2·45	657	3·18	24	3·63	40	4·00
North Canterbury ..	325	3·61	471	3·98	9	3·67	21	4·98
Otago	742	4·37	1,517	6·99	48	3·85	67	8·75
Southland	162	2·78	222	4·38	18	4·94	7	6·21
Waimarino	220	1·94	290	3·36	13	3·00	15	4·23
Wellington	223	2·34	315	4·04	14	4·71	17	5·97
All districts ..	2,733	3·20	4,348	4·88	152	4·14	204	6·17

the river per day in the first two months of the season, May and June, than in July and August, although there was a revival of activity in September. He also found that about half the fishing was done on Saturdays and Sundays. Rupp states that on Sunkhaze Stream, Maine, 89 per cent of the effort was exerted in the first 14 weeks of the 18 week season and that 54 per cent was on weekends, holidays, and the opening day.

5. LONG-TERM CHANGES IN EFFORT

SUMMARY

Past changes in total angling effort can be deduced only from the number of licences sold. They are summarised in Fig. 24. The number of licences increased fairly steadily from the beginning of angling in 1883 until the beginning of the war in 1939; there was a check during the war, but since then it has increased much more rapidly than before. At present the number of anglers is doubling every six years. The percentage of anglers in the adult male population rose steadily to slightly over 1 per cent by 1900. It then remained almost constant until 1946, but then began to rise rapidly and reached 2·8 per cent in 1953–54.

The above figures are based on the number of licences sold by acclimatisation societies, but in addition numerous licences are sold for the Government-controlled districts. Angling in these areas commenced relatively late, but in recent years developments have paralleled those in the society districts. Although many of the licences sold in these districts are for short periods, they are equivalent in angling effort to about 60 per cent of the whole-season licences sold by societies. Some but not all of the anglers in Government-controlled districts also hold society licences. The total number of anglers in the country is therefore rather greater than the number of society licence holders, but not as much as 60 per cent greater. About 0·3 per cent of women and 4·0 per cent of boys hold fishing licences.

The present intensity of angling on the most heavily fished New Zealand rivers is about 1,000 angler-hours per mile or 150 angler-hours per acre per season. Comparable North American data show that streams supporting intensities up to about this level are not often stocked, but that more heavily fished waters are stocked with takable fish although the actual need for this has not often been demonstrated. In view of the present rapid increase of angling in New Zealand there is therefore need to maintain a careful watch on the state of stocks in our more heavily fished waters.

The total angling effort is the product of the average individual effort and the number of anglers. A full study of changes in total effort would call for investigation of both those factors. Unfortunately, the data regarding the amount of fishing done by individual anglers before the inauguration of the general diary scheme is so fragmentary as to be useless for comparative purposes. Study of change in effort is therefore limited to changes in the number of anglers as shown by the number of

Table 37. Changes in Number of Licences Sold, and in the Resulting Revenue, Compared With Changes in the Relevant Part of the Population

Year	(1) Acclimatisation Society Revenue (× £1,000)	(2) Government Revenue (× £1,000)	(3) Men's Whole-season Licences (Societies) (× 1,000)	(4) Population, Males 18 and Over (× 1,000)	(5) Percentage of Licence Holders
1883	0·4	..	0·3	175	0·17
1893	1·6	..	1·2	213	0·57
1903	3·9	..	2·9	285	1·03
1913	5·1	..	3·8	355	1·08
1923	7·3	..	5·4	426	1·28
1933	9·2	2·8	6·9	515	1·34
1938	11·4	4·6	6·7	550	1·21
1946	11·8	7·2	7·5	570	1·32
1947	13·9	8·1	8·8	583	1·51
1948	16·1	9·2	10·3	595	1·73
1949	17·4	9·7	11·1	611	1·81
1950	22·1	10·4	12·6	625	2·02
1951	23·3	11·7	13·3	638	2·07
1952	28·4	14·2	14·8	651	2·27
1953	30·6	16·4	16·1	666	2·42
1954	34·1	24·0	18·9	680	2·80

licences sold. The main data available are summarised in Table 37. This is divided into two sections: the upper part, covering the period up to the 1939–45 war, outlines the results, generally at ten-year intervals; the lower section, covering the post-war period, is more detailed, showing the figures for each year. The data are also shown graphically in Fig. 24.

In the table, column 1 shows the total revenue received by acclimatisation societies from the sale of fishing licences. In the upper section the figures are derived from Hobbs (1948) by correcting the figures given for the six major societies in his Table IX on the assumption that the proportion of total New Zealand revenue received by them remained constant throughout at the 1936 figure of 84 per cent. In the lower section the actual figures derived from returns supplied to the Marine Department by each society have been used. It is evident that revenue increased fairly steadily until 1946 but that since that year the rate has been much more rapid. This increase in revenue has been derived mainly from an increase in the number of licences sold, but it has been added to by several rises in the cost of licences.

Whole-season licences cost £1 from their inauguration until 1936. They were then raised to £1 5s. In 1942 there was a further rise, in the North Island only, to £1 10s. In 1949 the South Island licence also was raised to £1 10s., but in 1951 the North Island licence was again advanced to £2. The total number of men's whole-season licences sold by societies is shown in column 3. The changes are very similar to those for total revenue: a fairly steady increase up to 1938, a check during the war period, and a very much more rapid rise during the post-war years. In this column also the figures in the lower section are based on exact returns, while those in the upper section are derived from Hobbs (1948) on the assumption that, as he states, £100 of licence revenue was, in this period, equivalent to 125 licences of all

kinds, and that, as in 1952, men's whole-season licences constituted 60 per cent of the total number of licences sold.

To determine the influence of population changes, the numbers of licences in column 3 have been compared with the size of the relevant section of the population (i.e. males of 18 years and over) in the same year. The population figures, which are derived by simple interpolation from the results of the five-yearly censuses, are shown in column 4, while column 5 shows the number of licence holders as a percentage of the population. The figures in this column are comparable with those in column 10 of Appendix 4. They show that the original build-up of interest in angling was complete soon after 1900, when about 1 per cent of the population were fishing. During the next 40 years there was only a slight further increase, and in the 1930's the figure was about 1·3 per cent. Since the war, interest has spread very rapidly, and in 8 years the percentage has more than doubled, reaching 2·8 per cent in the 1953–54 season.

The actual percentages of adult males who fish are greater than those shown in column 5, since this compares with the total population only the number of licences sold by acclimatisation societies. Large numbers of licences are also sold for the

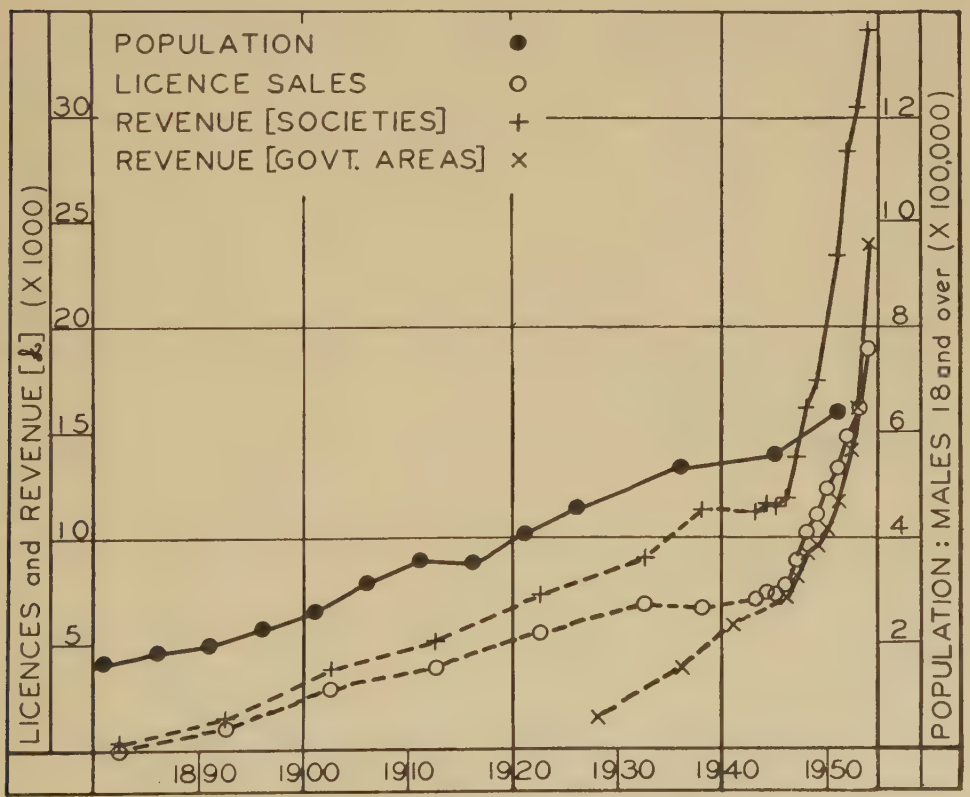


Fig. 24: The number of men's whole-season licences sold, the revenue received from the sale of licences by acclimatisation societies and by the Department of Internal Affairs, and the population of males of 18 years and over, from the commencement of angling in New Zealand.

Table 38. The Estimated Intensity of Angling on Nine Major Rivers in 1951–52, and on the Main Water of the Horokiwi Stream in 1939–40

Acclimatisation District	River	Length (Miles)	Area (Acres)	Total Hours (× 1,000)	Hours/Mile	Hours/Acre
Otago-Southland	Mataura	70	850	65·3	930	77
Southland	Waiau	40	1,900	36·7	920	19
Otago	Pomahaka	50	420	44·3	890	106
Otago	Waipahi	24	120	16·7	700	140
South Canterbury	Opihi	40	240	26·5	660	110
Southland	Aparima	46	560	28·3	620	51
Otago	Shag	24	120	6·6	270	55
Southland	Oreti	70	1,400	17·6	250	13
Wellington	Horokiwi	3·2	5·6	0·5	165	94
Nelson	Motueka	40	480	5·5	140	11

Table 39. Published Data on Angling Intensity on a Number of North American Streams

	Length (Miles)	Area (Acres)	Total Hours (× 1,000)	Hours/Mile	Hours/Acre	Reference	Comments
Spring Creek, Pennsylvania	1	..	44*	44,000*	..	Pennsylvania Fish Commission, 1954	Very heavily stocked – "Anglers' Paradise".
Blackledge River, Connecticut	1·7	..	9·7	5,700	..	Thorpe, *et al*, 1947	Heavily stocked. Special research project.
Farnsworth Branch, Pennsylvania	6	..	10·8	1,800	..	Pennsylvania Fish Commission, 1954	Heavily stocked.
Pigeon River, Michigan	4·8	24	6·7	1,400	280	Cooper, 1953	Heavily stocked. Mean of three seasons.
Sunkhaze Stream, Maine	3·4	6·2	3·1	910	500	Rupp, 1955	No stocking data. Mean of three seasons.
Various streams, Michigan	1–12	3·0–57·5	0·6–15·2	..	41–296	Shetter, 1944	Nine streams. Mainly wild fish caught.
Furnace Brook, Vermont	6·5	20	3·5	550	175	Lord, 1946	Heaviest of eleven seasons. Mainly wild fish caught.
Battenkill River, Vermont	20	145	10·2	510	70	Lord, 1946	Heaviest of five seasons. Mainly wild fish caught.
Pisgah National Forest, North Carolina	148	..	25	170	†	Chamberlain, 1943	Heaviest of five seasons. Combined results of many streams. About half catch from liberated fish.
Crystal Creek, New York	4·2	12·3	0·46	110	37	Schuck, 1945	Mean of three seasons. Experimental area. No stocking.

*Days, no data given on hours fished.
†Available data suggests an intensity of about 60 hours/acre.

Government-controlled Taupo, Rotorua, and Southern Lakes districts. Column 2 of Table 37 shows the revenue received from the sale of licences for these districts. Relatively few data are available for the pre-war years, and the figures for 1933 and 1938 have been obtained by interpolation between the years for which there are reliable figures. The figures for the second period are accurate, and have been obtained from the files of the Department of Internal Affairs. In recent years the total value of these licences has been between a half and two-thirds of those sold by societies. Column 4 of Appendix 4 shows that in 1951–52 the total number of licences sold in Government-controlled districts, when converted to the equivalent number of whole-season licences (9,107), was 62 per cent of those sold by societies (14,794). An unknown proportion of anglers in these districts also fish in society-controlled districts and therefore hold two licences. The percentage of anglers in the adult male population is therefore greater than is shown in Table 37, but not as much as 60 per cent more. The figures also do not make allowance for men who fish less frequently and only take out short-period licences.

The proportions of anglers in the other groups of the population, women, and girls and boys under 18, are different from those for men. At the 1951 census the population contained 647,578 women of 18 years and over. Of these 2,150 held whole-season fishing licences issued by societies in 1951–52. This is only 0·33 per cent compared with the figure of 2·27 per cent for men. At the same date there were 622,158 children under 18 years, and of these 7,369 or 1·18 per cent held licences. Nearly all these licences would be held by boys in the upper half of this age group. It therefore appears that the proportion of boys between 10 and 17 years who hold fishing licences is at least 4 per cent.

The rapid increase in the number of anglers since the war is not yet showing any sign of slowing down. A logarithmic plot shows that over the post-war period the rate of increase amounts approximately to a doubling of the number of anglers every six years.

If this increase continues in the future, it must lead on some waters to angling pressures considerably in excess of those so far experienced, and these in turn will bring up new problems of management. The position may be automatically met to some extent by a greater tendency for anglers to visit the more remote waters so that the increase in effort will be greater on these and less on the waters already heavily fished. There is considerable evidence that this process has occurred in the past and it seems likely that it will continue in the future, particularly as access is improved to areas which are now remote.

In view of the continuing increase, it is desirable to attempt an assessment of the present intensity of angling on popular New Zealand rivers. This has been done for a number of rivers in Table 38. The length of fishing water on each river has been measured approximately on 4 miles to 1 inch survey maps and has been multiplied by a subjective estimate of average width to obtain the approximate area. The estimates of hours fished have been made by the method described when dealing with the distribution of effort within districts. The rivers selected for inclusion in the table are popular waters for which adequate data are available. Also included in the table are the corresponding figures for the main water of the Horokiwi Stream; these figures refer to the 1939–40 season, which was that in which the greatest amount of fishing was recorded in this stream (Allen, 1951).

Although the various approximations which have been made in compiling this table are such that the individual results have a rather low standard of accuracy,

they probably indicate reasonably closely the general level of angling intensity on the most popular New Zealand rivers at the present time. This appears to be about 1000 angler-hours per mile per season, or 150 angler-hours per acre per season.

This level of intensity can be compared with that recorded from waters which have been studied in other countries, particularly the U.S.A. Data from ten sources are set out in Table 39. The top example is clearly very exceptional: it refers to closely controlled fishing in a short length of water which is kept heavily stocked with fish, including some of large size. The second example appears also to be abnormal. It refers to an experiment designed to determine the rate of removal of liberated fish by heavy angling. The remainder form a connected series which is very similar to the New Zealand series except that the Farnsworth Branch and Pigeon River rather exceed New Zealand intensities.

Similar data for a number of Massachusetts streams have been published by Mullan (1955), who states: "Average angling effort expended per total surface acres per season are light to heavy, perhaps averaging about 100 to 150 angler hours state wide, but favourite or readily accessible stretches or streams near large cities may be subjected to 300 to 1,000 angler hours with corresponding less attractive or accessible areas receiving light pressures of well under 100 angler hours." Large-scale liberations of takable fish are practised in this state and in the larger main streams hatchery-produced fish are believed to make up 90 to 95 per cent of the catch. In smaller streams the hatchery contribution is much less.

Useful information on methods of management can be derived from these data. The comments in Table 39, which are based on statements made in the original publications, show a clear correlation between angling intensity and extent of liberations. The waters in the upper part of the table apparently depend on the liberation of considerable numbers of takable fish to maintain the high angling intensity; those in the lower part of the table rely primarily on naturally produced fish. The division between the two sections falls at or rather above the level which now prevails on the most heavily fished New Zealand waters. It appears, therefore, that in North America satisfactory angling can be maintained under angling pressures as heavy as any in New Zealand without recourse to artificial stocking. It also appears, however, that if the present rate of increase continues, intensities may soon be reached on some of the most popular New Zealand waters which will equal those found on some American waters where liberations of takable fish are regularly made. Whether this practice is necessary at those levels of intensity does not yet appear to be fully established by investigation, but the situation indicates the need to keep a close watch on the size and abundance of fish being taken by anglers in the most popular waters. It must be realised that the intensities given in Table 38 are estimated averages over many miles of water, and that on most of these rivers the intensity on the most popular or most accessible reaches will be several times as great. Fish populations are, however, generally continuous throughout the length of each river, and it is probably the average angling intensities which are significant.

V THE CATCH

SUMMARY

The recorded individual catch for a season varied from 0 to 508 fish, and the district means ranged from 21 to 105. Except in the south-east of the South Island, where higher catches prevailed, the mean was generally between 25 and 40. The distribution of seasonal catch in a district seems to conform to the negative binomial distribution. The estimate of seasonal catch obtained from the diary data seems to be biased by the tendency of diarists to fish more often than other anglers. Comparison with the results of a canvass of a small random sample of anglers suggests that the diary data may also be deficient in very large catches. The estimates of district mean rate of catch are not believed to be significantly biased either by non-representativeness of the diarists in their individual rates of catch or by inadequate distribution over the waters of the district.

The best estimates of total district catch are therefore obtained by multiplying number of anglers, mean number of hours fished per season, and mean rate of catch. They are shown in Appendix 4, column 15. By multiplying these by the district mean weights estimates of total weight of catch are also obtained (column 16).

The two most productive areas are the Rotorua-Taupo area in the North Island, with a lake fishery for large rainbow trout, and the south-east of the South Island, with a river fishery for relatively small brown trout. Together, these districts, covering 29 per cent of New Zealand, yield three-quarters of the trout caught.

The total weight of trout caught in a season (about 23,000 cwt.) is about 5 per cent of the commercial catch of sea fish landed in New Zealand.

An estimate of the total quantities of fish taken in each district can be made by assessing the total angling effort and the average catch per unit effort. Three alternative units of effort are possible: the individual angler, the angling day, and the angling hour.

The total catch for the season varies greatly from angler to angler, and the distributions in each district are summarised in Table 40. In most districts the average catch of those anglers who kept diaries was between 30 and 40 fish, and relatively few anglers took more than 100 fish in a season. The group of districts in the south-east of the South Island – South Canterbury, Otago, and Southland – differs somewhat from the others. In them the average catch is much higher, and catches of over 100 fish a season are common, the largest recorded in the diaries being 508. It has already been shown that these are the most heavily fished of the society-controlled districts and that in Otago and Southland the total fishing effort per angler is higher than in any other district, while in South Canterbury it is also very high. Table 41 shows the percentage distribution of seasonal catch in four typical districts, Southland and Otago representing the group with very high catches, and

Table 40. The Distribution for Each District of the Number of Fish Caught by Individual Anglers in a Season

District	Number of Fish Caught in a Season													Total Number of Diaries	Mean Number of Fish
	0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100	101–150	151–200	201–		
Ashburton	7	8	2	2	2	3	..	..	1	1	3	..	..	29	36·1
Auckland	11	20	13	5	6	12	7	3	7	1	12	1	..	98	48·3
East Coast	5	5	1	1	3	..	..	..	..	..	..	..	..	15	21·5
Hawke's Bay	5	8	7	10	6	1	4	2	..	2	3	..	..	48	39·9
Nelson	43	50	42	29	18	14	12	10	5	4	8	3	2	240	37·9
Marlborough	3	3	2	2	1	..	..	..	..	..	1	..	..	12	27·9
North Canterbury	15	14	14	7	6	7	1	1	..	1	2	2	..	70	33·9
Otago	34	37	43	29	45	25	22	21	20	17	61	31	38	423	85·6
South Canterbury	1	8	3	5	10	4	5	3	4	3	9	2	2	59	69·0
Southland	8	13	3	8	7	3	6	4	12	4	29	24	12	133	105·4
Taranaki-Hawera	5	13	6	5	4	1	..	3	1	..	1	1	..	40	35·0
Waimarino	26	21	19	15	8	2	2	4	..	2	5	2	1	107	36·8
Wellington	11	14	12	11	11	4	3	3	6	1	2	4	..	82	44·2
West Coast	2	4	3	9	3	1	3	1	..	..	2	..	..	28	41·3
Westland	1	1	1	..	1	1	..	..	..	..	..	..	..	5	30·4
South-east	43	58	49	42	62	32	33	28	36	24	99	57	52	615	88·3
Others	134	161	122	96	69	46	32	27	20	12	39	13	3	774	38·9
Total	177	219	171	138	131	78	65	55	56	36	138	70	55	1,389	60·8

Table 41. The Percentage Distribution of Number of Fish Caught by Individual Anglers in a Season, Based on Diaries From Four of the Principal Districts, and a Personal Canvass of Nelson Anglers in 1950

	Number of Fish Caught in a Season											
	0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100	101–150	151–200	201–
Diaries													
Southland	6·0	9·8	2·3	6·0	5·3	2·3	4·5	3·0	9·0	3·0	21·8	18·0	9·0
Otago	8·0	8·7	10·2	6·9	10·6	5·9	5·2	5·0	4·7	4·0	14·4	7·3	9·0
Waimarino	24·3	19·6	17·7	14·0	7·5	1·9	1·9	3·7	..	1·9	4·7	1·9	0·9
Nelson	17·9	20·8	17·5	12·1	7·5	5·8	5·0	4·2	2·1	1·7	3·3	1·3	0·8
Canvass													
Nelson	45·6	16·5	6·8	3·9	3·9	2·9	4·9	1·9	1·0	1·9	5·8	3·9	1·0

Waimarino and Nelson the remainder. In the first two districts about 50 per cent and 30 per cent respectively of the catches are greater than 100, but in the other two the corresponding percentages are 7·5 and 5·4.

The general form of the distribution is similar to that for the number of days fished per season; the mode is at a fairly small number and there is a long tail running up to relatively high values. A test of the Nelson data by the method of Bliss and Fisher (1953) showed that they fitted satisfactorily to a negative binomial distribution with $m = 37{\cdot}90$ and $k = 1{\cdot}30$.

The means given in Table 40 provide an estimate of the true average catch per angler, which could be used in estimating the total district catch. They are, however, liable to bias owing to failure of the diarists to be truly representative of the anglers as a whole. This problem has already been discussed in relation to the fishing effort and it was shown that the recorded mean was an overestimate of the true average effort. This effect will tend to cause a similar bias in the estimate of catch, but it could be further complicated if there were differences in the catch per unit effort between anglers who kept diaries and those who did not. Such an effect might be expected to take the form of an increase in rate of catch with increase in total effort; in other words, the anglers who fish most often are the most skilful. To test this effect, the data provided by the seven anglers whose records have been used in Fig. 16 and in a previous paper (Allen, 1955) have again been used. Their diaries showed that they fished their favourite stream very frequently for a number of years, and in Table 42 their rates of catch are compared with those of other anglers who fished the same waters less regularly. Of the seven, four achieved rates higher than the general average, but the other three were lower than the average by quite substantial amounts. This does not suggest that it is necessary to allow for failure of the diarists to be representative as far as rate of catch is concerned. The correction for overestimate of effort can therefore be applied directly to the seasonal catch.

As discussed earlier, one attempt was made to obtain an independent check on the seasonal catch. In 1950, after the close of the fishing season, a visit was made to the Nelson Acclimatisation District and as many anglers were interviewed as was possible in the time available. The part of the district covered was Waimea county and the included towns, and the adjoining Takaka area. Within the area the anglers chosen for interview were as far as possible taken at random although a few living in places remote from other anglers or convenient routes of travel were deliberately

Table 42. Comparison Between the Average Rates of Catch Obtained by Certain Individuals Who Fished Certain Waters Particularly Frequently, and the General Mean Rate on the Same Waters

Water	Angler	Individual		General	
		Hours Fished	Fish Per Hour	Hours Fished	Fish Per Hour
Tukituki	A	693	0·50	2,073	0·45
Tukituki	B	511	0·36	2,073	0·45
Motueka	C	582	1·38	4,989	0·76
Clutha	D	1,429	0·74	4,462	0·61
Waipahi	E	932	1·07	3,312	0·78
Pomahaka	F	1,160	0·64	7,949	1·02
Pomahaka	G	633	0·70	7,949	1·02

omitted so as to give the best possible use of the available time. Of 259 holders of men's whole-season licences in the area 102 were contacted and a further 26 had already sent in diaries. Of those contacted 13 produced diaries which they had kept during the previous season but failed to send in.

The anglers who had not kept diaries were asked to estimate as accurately as possible the number of fish they had caught in the previous season. Almost without exception they proved fully co-operative and did their best to give accurate replies. The results of these replies and of a further 14 obtained from holders of other classes of licences are shown in the bottom line of Table 41 and may be directly compared with the general diary results for the same district shown on the line above. Two main differences can be seen. The canvass gave a much greater proportion of anglers catching 10 fish or fewer per season, but at the other extreme it also showed a greater proportion taking large numbers per season. The effects on the mean of these two differences largely cancel each other out and the mean of the canvass results (42·1) was only about 10 per cent higher than that given by the diaries (37·9). The greater number of low catches in the canvass results seems likely to be due to a not unnatural feeling on the part of anglers who do little fishing that their results are not worth recording. The excess of high catches is more difficult to assess. It may be that some anglers taking large numbers of fish do not want to disclose how big their catches are, but on the other hand there may have been some exaggeration, deliberate or unconscious, in the verbal estimates given to the canvasser. This small independent check suggests, therefore, that the mean seasonal catch as recorded in the diaries could be used as a satisfactory estimate of the true mean.

The other units of effort which can be used in estimating the total district catch are based on time, i.e., the day or the hour. Of these the hour seems to be the more suitable although it has been shown earlier that the catch per hour is not independent of the length of the fishing day. An estimate of the total number of hours fished in each district in the 1951–52 season is given in Appendix 4. There is no evidence that the diaries are not representative of the whole fishing population as far as length of day is concerned, and therefore this estimate is not likely to be biased by variations in length of fishing day. The evidence considered earlier in this section did not indicate that the diarists were likely to have a higher rate of catch than the rest of the anglers. Lack of a representative distribution of effort over the waters of the district is therefore likely to be the biggest source of error in estimating the average rate of catch. This will vary greatly from district to district, largely according to the proportion of anglers sending in diaries, and it may be expected to be least where the largest proportion of anglers co-operated. The results of the Nelson canvass can be used to test the extent of the error in a district where there is a relatively high degree of co-operation. Table 43 compares the number of fish taken in the 1949–50 season in various waters of the district by the anglers contacted personally and by those resident in the same area who sent in diaries. It is obvious that the general pattern is very similar although the difference is highly significant statistically. To test the effect of the differences on the rate of catch, mean rates were worked out for each group of anglers, using the data in Appendix 1 as a basis. The group means for diarists and non-diarists were respectively 0·67 and 0·68 fish per hour and are clearly not significantly different. The overall district means obtained by pooling all available diary data for each district therefore seem to give satisfactory estimates for those districts where substantial numbers of diaries were

Table 43. Comparison of the Numbers and Percentage Distribution of Fish Taken From the Main Groups of Waters in the Nelson District Between Anglers Sending in Diaries and Those Canvassed Personally

Waters	Diaries		Canvass	
	Number	Percentage	Number	Percentage
Eastern rivers	110	6·8	51	1·6
Maitai	73	4·5	188	5·9
Waimea system	74	4·5	189	5·9
Motueka system	818	50·2	1,880	59·1
Riwaka	186	11·4	114	3·6
Western rivers	15	0·9	6	0·2
Buller system	353	21·7	753	23·7
	1,629	100·0	3,181	100·0

returned. Where only a few diaries are available the reliability is less but the estimates obtained in this way remain the best available.

In Appendix 4 this method is used to obtain estimates of the total catch in each district. Column 11 shows the overall mean rate of catch in fish per hour for the district. Column 14 shows the estimated average seasonal catch per angler obtained by multiplying the mean rate by the mean hours per season shown in column 3. The estimates of catch obtained in this way are less than those given in Table 40, usually by about 30 per cent. This is principally because the estimates of hours fished per season have been adjusted for the apparent tendency of diarists to fish more than the average. In view of the indication given by the Nelson canvass that anglers catching very large numbers of fish are apparently inadequately represented in the diaries, the estimates of catch given in the appendix may be considered minimal, and those given in Table 40 as maximal. The estimates for the three Government-controlled districts have not been adjusted for non-representativeness since they are based on data collected by different techniques; they must therefore be regarded as the best available estimates and have no known bias. For the districts for which no diary data were available mean rates of catch were assumed to be 0·6 in the North Island and 0·75 in the South Island.

Estimates of the total number of fish caught in each district are shown in column 15. These have been obtained by multiplying the average individual catch by the number of whole-season licence holders shown in column 4. Finally the data are used to estimate the total weight of fish caught in each district (column 16). To do this the estimated numbers are multiplied by the district mean weights (column 12) obtained from the pooled data for each district. For districts where there were no diary data, means of 2·2 lb. and 1·4 lb. were assumed for the North and South Islands respectively. The accuracy of the district mean weights will be influenced by the factors which have already been discussed in connection with the district mean rates of catch. The Nelson canvass results have again been used to give a check, and the district mean calculated from them is 2·34 lb. as against 2·25 lb. from the diary records for the same season. The difference is negligible.

The main features of the catch are summarised in Table 44. This shows the contribution which is made to the catch by the Government-controlled districts, which are fished essentially by visitors from other parts of the country. In the North Island

Table 44. The Estimated Total Numbers and Weights of Trout Caught in 1951–52 in the Society- and Government-controlled Districts in the North and South Islands and New Zealand as a Whole

		Number (× 1,000)	Weight (× 1,000 lb.)
North Island	Society districts	120·3	242·6
	Government districts	358·6	1,486·8
	Total	478·9	1,729·4
South Island	Society districts	466·1	767·3
	Government districts	24·7	77·4
	Total	490·8	844·7
Combined	Society districts	586·4	1,009·9
	Government districts	383·3	1,564·2
	Total	969·7	2,574·1

these districts provide about 75 per cent by number and 86 per cent by weight of the catch; in the South Island the contribution of the Southern Lakes district is relatively small, but over the whole country the contribution from these districts is about 40 per cent by number and 61 per cent by weight.

The only other compact area which makes a major contribution to the total catch is the group of districts in the south-east of the South Island: Southland, Otago, Waitaki, Waimate, and South Canterbury. These districts yield about 77 per cent by number and 67 per cent by weight of the South Island catch. The two main fish-producing areas are thus the Rotorua-Taupo area in the North Island and the south-east area of the South Island. Between them these two areas, which occupy about 29 per cent of the land area of New Zealand, yield about 76 per cent by number and 80 per cent by weight of the fish caught. It should be noted that these two productive regions possess fisheries of very different kinds. That in the North Island is essentially a lake fishery for large rainbow trout, and is supported by visiting anglers from all parts of the island. The South Island one is a river fishery for relatively small brown trout and is fished mainly by local residents.

In the above comparisons there may be a slight tendency to overestimate the proportional contribution made by the Government-controlled districts. This will arise partly because the estimates used for the society districts are believed to be minimal for reasons already discussed, while there is no known bias in the Government district data, and partly because anglers other than men holding whole-season licences are ignored in the society districts but have been included in the Government districts on account of their much greater numbers in these areas.

A large proportion of the trout caught are ultimately eaten by the anglers and their families and friends. It is interesting therefore to compare the total weight of trout with the weight of fish caught and marketed by the commercial sea fisheries of New Zealand. The recorded weight of "wet fish" landed in 1952 was 408,858 cwt. (New Zealand Marine Department, 1953). The estimated total weight of trout caught in 1951–52, as shown in Table 44, is approximately 23,000 cwt. This is 5·6 per cent of the commercial catch. The actual percentage will be rather less since part of the commercial catch is gutted or prepared in other ways prior to weighing, while the estimated weights of trout are based on the entire fish. It appears, however, that angling contributes about one-twentieth of the entire amount of fresh

or smoked fish consumed in New Zealand. Only five commercially caught species are landed in greater quantities than trout.

The continuing increase in fishing effort, which has been discussed earlier, is probably bringing with it an increase in the total seasonal catch. It has been shown in a previous section that in some waters there are signs that the catch per unit effort is decreasing. This will cause the total catch to increase more slowly than the effort. Ultimately a point may be reached at which, under present methods of management, the rate of catch decreases as rapidly as effort increases, so that the total catch is stable. If unrestricted fishing is allowed to increase beyond this point, overfishing may lead to the depletion of stocks. The data presented in this investigation have provided for the first time a reference point which will make it possible to observe future trends with sufficient accuracy to reveal any major changes in time to consider remedial measures.

VI THE EFFECT OF REGULATIONS

1. THE SIZE LIMIT

SUMMARY

It is not at present possible to determine the importance of size limits in maintaining adequate breeding stocks, but their effect in enabling the best yield to be obtained from an existing breeding stock can be assessed.

The use of size limits for this purpose assumes that the small fish returned as undersized will ultimately add more to anglers' catches by being recaught when larger than they would by being retained when originally caught. If it is assumed that there is no competition for food, the value of the size limit giving the greatest total weight of catch can be determined from $W = RV$ where W and V are the mean weights at limiting size and capture respectively, and R is the proportion of takable fish ultimately caught by anglers. W/V has been determined for the waters given in Appendix 1 and found to range from 0·06 to 0·96. The maximum value of R in heavily fished New Zealand waters is believed to be about 0·3. Thus all waters in which W/V is greater than 0·3, as well as some others, have size limits which are too high and lead to an unnecessary reduction in the quantity of fish obtained by anglers. On account of the general practice of imposing a uniform size limit throughout each district without regard for the varying nature of the local stocks, W/V varies widely within districts, although some districts show consistently lower and more appropriate values than others. In about three-quarters of the waters examined the size limits appear to be wastefully high.

If competition for food between large and small fish is commonly significant, the proportion of waters in which size limits are too high will be even greater.

The direct effect of the size limit is to cause fish of less than legal size to be returned to the water when they would otherwise have been kept by anglers. The actual proportions of fish returned as undersized in various waters and with different fishing methods have been discussed in an earlier section. Great variation occurs; the proportion of undersized fish has a strong negative correlation with the mean length, but is correlated with the value of the size limit only for groups of waters in which the mean length is the same. Over the entire sample of waters studied, the positive correlation between mean length of takable fish caught and size limit is sufficient to mask the correlation between the latter and proportion of undersized fish.

The use of size limits in the management of fish stocks rests on the assumption that of the small fish released, enough will survive for sufficient time to maintain or increase the catch, either by being caught themselves when of larger size or by adding to subsequent generations by spawning. The conditions under which size limits will help to give maintained or improved catches have been discussed elsewhere (Allen, 1953, 1954). It was shown that, at the present level of knowledge of

the characteristics of fish populations, the only effect of the size limit which can be tested with any degree of reliability is its influence on the total weight of fish caught, assuming that there is no significant competition for food. When the value of the size limit is that which gives the greatest weight of catch, $W = RV\ (1 - GF_2/F_1)$,* where W is the mean individual weight at limiting size,

V is the mean individual weight at capture,

R is the proportion of fish reaching takable size which are ultimately caught (angling efficiency),

G is the proportion of the food of older fish which would be eaten by younger fish if it became available to them, and

F_1 and F_2 are the total amounts of food eaten by fish smaller and greater than the size limit respectively.

When there is no competition for food $G = 0$ and $W = RV$. It is not possible at present to estimate the value of G even approximately, but any positive value will reduce the value of W. Thus the optimum size limit is maximal when estimated on the assumption that no competition occurs.

The correctness of existing size limits can only be determined if the value of W/V can be compared with the angling efficiency (R) for the same waters. The only New Zealand water for which R has been directly estimated is the Horokiwi, where a value of 0·29 prevailed about 1940 (Allen, 1954). Comparisons of angling intensity as shown in Table 38, and of the rate at which number decreases with increasing size, suggests that R is likely to be as heavy on the Horokiwi as on any New Zealand waters. A value of 0·3 has therefore been assumed to be the maximum occurring in New Zealand, and the size limit has been considered to be too high on any water where W/V is greater than this.

Table 45 shows the distribution in each district of the value of W/V for the waters in Appendix 1. Of the 130 waters in the table, 72 have W/V greater than 0·3. Some of those with lower values will be relatively lightly fished so that R will still be less than W/V. Thus it appears that in this sample of waters, most of which are locally important fishing streams, about three-quarters were fished under a size limit which was too high and prevented the greatest possible weight of catch from being achieved.

The table also shows that within most districts there is wide variation in the value of W/V. The variation arises usually from the imposition of a single size limit over all the waters of the district despite large differences in the normal size of fish caught. These variations within districts emphasise the necessity of taking into consideration the characteristics of individual trout stocks if size limits are to be used effectively to assist in obtaining the maximum yield. The uniform limits over whole acclimatisation districts which are now general are administratively simple and easy to enforce but may produce undesirable effects.

There are, however, some variations between districts in the relation between the size limit and the usual size of fish caught. Thus in the Ashburton, Marlborough, West Coast, and Westland districts all the ten waters for which data are available gave values of W/V of less than 0·3. On the other hand, among 29 waters in the East Coast, Hawke's Bay, South Canterbury, Southland and Waitaki districts, 23 had W/V greater than 0·3. It appears, therefore, that in the second group of districts the size limits in force in 1947–52 tended to be too high to allow the maximum

*In Allen (1954) the last term of this equation was inadvertently printed upside down.

Table 45. The Distribution in Each District of the Value of W/V for the Waters Included in Appendix 1

District	0·05–0·09	0·10–0·14	0·15–0·19	0·20–0·24	0·25–0·29	0·30–0·34	0·35–0·39	0·40–0·44	0·45–0·49	0·50–0·54	0·55–0·59	0·60–0·64	0·65–0·69	0·70–	Total
Ashburton	..	..	1	1	1	..	..	..	..	..	..	..	..	..	3
Auckland	..	..	..	2	3	3	2	1	1	..	..	1	..	..	13
East Coast	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1
Hawke's Bay	..	..	..	..	1	1	2	1	1	..	..	..	..	..	6
Marlborough	1	..	..	..	..	..	..	..	..	..	..	..	..	..	1
Nelson	..	..	4	3	2	2	..	2	..	1	..	..	2	..	16
North Canterbury	..	..	..	2	3	2	..	1	1	1	..	..	..	1	11
Otago	..	1	2	5	3	6	2	3	2	..	1	..	1	..	26
South Canterbury	..	..	..	..	2	1	1	..	..	1	1	1	..	..	7
Southland	..	1	..	1	1	3	2	3	1	..	2	..	..	..	14
Taranaki-Hawera	..	..	..	2	1	2	1	..	..	..	..	..	..	..	6
Waimarino	..	1	1	2	..	..	..	..	1	..	1	..	..	..	6
Waitaki	..	..	..	..	..	..	..	1	..	..	..	..	..	..	1
Wellington	..	..	1	1	2	3	..	2	..	1	..	..	..	..	10
West Coast	1	3	1	..	..	..	..	..	..	..	..	..	..	..	5
Westland	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Otago-Southland	..	..	..	..	..	..	..	1	..	..	..	..	..	..	1
Ashburton - North Canterbury	..	..	1	..	..	..	..	..	..	..	..	..	..	..	1
Auckland-Waimarino	..	..	..	..	..	..	..	1	..	..	..	..	..	..	1
Total	2	7	11	19	19	23	11	16	7	4	5	2	3	1	130

yield being taken by anglers, while in the first group they were closer to the correct value or may even have been too low. In the remaining districts a more even distribution round 0·3 is found.

When W/V is equal to R, the size limit already has the best value. When the two quantities are not equal, the optimum value can be estimated by a method of successive approximations (Allen, 1953).

Within most individual waters the fish caught by anglers fall mainly within a relative small range of sizes and have size distributions of rather similar shape although with widely different means. For a given rate of exploitation the ratio between the average size and the optimum limit is constant, so that the proportion in anglers' catches of fish smaller than the optimum size limit will tend to be independent of the mean size. In lightly fished waters, therefore, the optimum size limit will be so low as to exclude a negligible number of fish whether the average size is large or small. Thus the desirability of having a size limit at all will depend more on the intensity of angling than on the average size of the fish. Size limits are most likely to be desirable where the angling pressure is particularly heavy and where the size range of fish caught, including undersized, is unusually wide.

The foregoing discussion is based on the assumption that no competition for food occurs. There is evidence that there may be significant competition in at least some trout populations and, in these circumstances, even lower values of the size limit will be desirable. Thus, if competition is generally significant, the proportion of waters in which existing limits are too high will be even greater than is indicated above.

Other bases for assessing the most desirable catch are possible and methods of estimating the correct size limits to produce them have been discussed elsewhere (Allen, 1954). Until more is known about what anglers really want, the total weight of catch, which has been used above, appears to provide the most reasonable basis which is susceptible to analytical treatment with the data and techniques now available.

The other major function which is often ascribed to a size limit is the preservation of an adequate breeding stock, but insufficient is yet known as to the relation between egg production, efficiency of spawning, and subsequent survival rates to allow the estimation of the optimum values for size limits from this point of view.

2. THE BAG LIMIT

SUMMARY

The effect of the bag limit is to reduce the average daily bag, and this can be estimated by fitting any series of data to the appropriate *log (n + 2) — normal distribution.* The reduction in daily catch is worked out in this way for each district and for a number of the principal waters. Within districts it varied from <0·1 to 5·0 per cent for limits in force in 1952 and there were considerable local variations within districts. In general the reduction was much greater in the South Island than in the North Island, where it never exceeded 0·2 per cent for any district. The variations in reduction in catch were due partly to local variations in limit and partly to variations in abundance of fish stocks. If a uniform bag limit of five were imposed throughout

Table 46. The Parameters n_{50} and q Which Define the Bag Distribution for Each District. Where the Bag Limit Was Changed During the Period Covered, and Where Different Limits Were in Force for Major Groups of Waters, These are Shown Separately

The table shows the percentage reduction in average daily bag (D) produced both by the actual limit and by a limit of five; also the percentage reduction in total catch (U) for a limit of five on the assumption that 30 per cent of takable fish are caught by anglers in the absence of a limit; also the expected percentage of limit bags (P).

District	Waters or Seasons	Limit	n_{50}	q	For Actual Limit D	For Limit of Five D	For Limit of Five U	P
					%	%		%
Ashburton	Lakes	8	0·55	1·71	0·9	4·7	3·3	0·8
	Others	12	0·90	1·80	0·9	10·2	7·3	0·5
Auckland	..	15	1·25	1·67	0·1	8·0	5·7	<0·1
East Coast	..	12	0·65	1·60	<0·1	3·3	2·3	<0·1
Hawke's Bay	..	15	0·20	1·66	<0·1	2·3	1·6	<0·1
Marlborough	..	10	0·70	1·59	0·1	3·5	2·4	0·1
Nelson	1946–49	5	1·20	1·64	6·9	6·9	4·9	5·3
	1949–52	8	0·70	1·80	2·5	7·8	5·6	1·8
North Canterbury ..	Lakes	8	0·85	1·73	1·6	7·3	5·2	1·2
	Others	10	0·55	1·73	0·5	5·3	3·8	0·3
Otago	1946–51	20	1·75	1·93	0·8	21·3	15·8	0·7
	1951–52	10	2·05	1·86	4·8	20·5	14·9	4·2
South Canterbury ..	Lakes	8	0·85	1·46	0·2	2·5	1·8	0·1
	Others	12	1·85	1·79	1·9	17·2	12·7	2·0
Southland	1947–51	15	2·05	1·77	0·7	17·0	12·5	0·8
	1951–52	10	1·80	1·90	5·0	20·0	14·8	4·2
Taranaki-Hawera ..	..	20	0·15	1·83	<0·1	4·7	3·3	<0·1
Waimarino	Not Wanganui ..	20	0·15	1·72	<0·1	2·0	1·4	<0·1
Waitaki	Kakanui	20	0·90	1·93	0·3	14·7	10·7	0·1
Wellington	..	12	0·95	1·69	0·2	6·6	4·7	0·2
West Coast	..	20	0·70	1·71	<0·1	5·5	3·8	<0·1
Westland	..	20	0·65	1·39	<0·1	1·3	0·9	<0·1

the country the reduction in the various districts would range from 1 to 16 per cent. In some districts local regulations impose specially low bag limits on a few waters and these seem generally to be appropriate to the stocks in them.

Some of the fish not caught because an angler has stopped on reaching his limit are ultimately caught later, so that the reduction in total catch is rather less than that in the daily bag.

The expectation of achieving a limit bag has been determined for the various districts and principal waters, and is found to be very similar to the percentage reduction in the catch.

The increase in catch caused by anglers continuing to fish in the hope of reaching their limit is generally negligible.

There is no appreciable benefit to less skilled anglers from any redistribution of catch which the bag limit causes by reducing the catches of the more successful anglers.

In general, existing bag limits have no significant effect on anglers' catches or on the conservation of fish stocks.

The effect of the bag limit has been discussed elsewhere (Allen, 1955). It was shown that the distribution of bags of different size, n, could be satisfactorily fitted by the *log (n + 2) — normal distribution* and that any given distribution was conveniently defined by the parameters n_{50}, the median value of n, and q, the antilog of the standard deviation of the transformed distribution. Methods of estimating these parameters were described, and curves were given showing the effects produced by different limits for various values of the parameters.

These techniques have been applied to the data obtained from the general diary scheme. An overall distribution table of daily bags was drawn up for each district from all available data. Where different bag limits were in force for different major groups of waters, or in different seasons, separate tables were compiled for each limit. From these distributions the values of n_{50} and q were estimated by the graphical method and the results are shown in columns 2 and 3 of Table 46.

The most important effect of the bag limit is to reduce to some extent the total angling catch. Figs. 3 and 4 in the paper referred to above show the direct reduction D produced by various limits for different combinations of n_{50} and q. By interpolation in these figures the appropriate values of D have been estimated for each district or other category in Table 46, the values being converted to percentages. Column 4 therefore shows the overall average effect of the limit actually in force in each case. Even although the small amount of data restricts the accuracy of some of the estimates the table shows clearly that the bag limits in force in 1951–52 generally caused a very small reduction in the total catch. In only three districts did the reduction exceed 2 per cent and in none did it exceed 5 per cent. In the North Island where the effect is generally less that in the South Island, the largest reduction was 0·2 per cent in Wellington. Since 1951–52 there have been changes in bag limit in a few of the minor districts, but these have had little effect on the general position.

The effect of the bag limit in any district depends partly on the value of the limit, and partly on the abundance of fish. To distinguish between these factors the reduction in catch has been estimated for all districts on the assumption that the same limit was in force throughout. For this purpose the value chosen for the limit

Table 47. The Values of n_{50} and q, the Expectation of a Limit Bag P, and the Percentage Reduction D in the Average Daily Bag Caused by the Limit in Force at the End of the Period of the Records for Some of the Principal Waters

District	Water	Limit	Number of Days	n_{50}	q	D	P
						%	%
Hawke's Bay	*Tukituki	15	927	0·41	1·64	<0·1	<0·1
Nelson	*Buller	8	521	0·84	1·57	0·6	0·3
	*Motueka	8	1,542	1·28	1·70	2·2	2·0
	Riwaka	8	325	1·15	1·69	1·8	1·5
	Wangapeka	8	248	0·90	1·69	1·3	1·2
North Canterbury	Lake Ellesmere	10	286	0·95	1·71	0·7	0·5
	Selwyn	10	389	0·65	1·82	1·1	0·7
	Waimakariri	10	277	0·30	1·67	0·4	<0·1
Otago	*Clutha	10	996	1·78	1·75	2·2	2·3
	Leith	10	319	1·35	1·95	4·9	2·8
	Mahinerangi-Waipori	10	386	1·20	1·71	1·0	0·8
	Mimihau	10	206	4·00	1·79	10·4	11·0
	*Pomahaka	10	1,740	2·54	1·91	8·2	7·0
	*Shag	5	282	0·54	1·68	4·2	2·6
	*Taieri	10	606	0·72	1·76	0·7	0·5
	Waikaia	10	207	1·85	1·75	3·0	2·2
	*Waipahi	10	641	2·41	2·04	14·5	7·8
	Waipori	10	216	0·90	1·87	2·0	1·3
	Waiwera	10	226	1·55	1·99	7·5	4·0
South Canterbury	*Opihi	12	300	1·72	1·69	0·7	0·6
Southland	*Aparima	10	620	2·27	1·81	4·4	4·4
	*Oreti	10	339	1·70	1·82	3·0	2·5
	*Waiau	10	838	1·30	1·70	1·0	0·9
Taranaki	Waiwakaiho	20	430	—0·05	1·57	<0·1	<0·1
Waimarino	Manganui-o-te-Ao	20	237	0·70	1·65	<0·1	<0·1
	Mangawhero	20	549	0·40	1·56	<0·1	<0·1
Wellington	*Horokiwi	12	362	0·75	1·68	0·2	0·2
	*Mangatainoka	12	350	1·28	1·64	0·3	0·2
West Coast	Grey	20	242	0·40	1·61	<0·1	<0·1
Auckland-Waimarino	*Wanganui	15	748	0·68	1·56	<0·1	<0·1
Otago-Southland	*Mataura	10	1,810	2·68	1·90	8·3	7·0

*The waters marked with an asterisk are those for which the values given are taken from Allen, 1955, Table 1.

was 5, which is the smallest value which has ever been applied in New Zealand to an entire district. The results are shown in column 5 of the table. It appears that both factors are contributing substantially to the irregular effects of existing limits. Thus Ashburton lakes and Taranaki-Hawera are evidently similar in abundance of fish since a limit of 5 would in each case cause a reduction of 4·7 per cent; the actual reductions are 0·9 per cent and <0·1 per cent and this difference seems to arise from the different limits of 8 and 20 respectively. In the same way Auckland and Nelson would show similar reductions with the same limit of 5, but under limits of 15 and 8 respectively the reductions are 0·1 and 2·5 per cent. On the other hand the difference between South Canterbury and Ashburton waters, other than lakes, evidently arises from differences in abundance, since, both with their present identical limits of 12 and with a hypothetical limit of 5, there is a substantial difference between the districts in the reduction produced by the limit. The same applies to North Canterbury and Otago, each with a limit of 10, and to Nelson and the Ashburton lakes, each with a limit of 8. Other similar comparisons can be made illustrating the influence of each of these factors. The relatively large reduction which is found in the districts in the south-east of the South Island is largely due to the relatively abundant stocks which have been shown earlier to exist in this area. There are no indications of any general tendency for district bag limits to be adjusted in accordance with abundance of fish stocks.

In the three Canterbury districts – North Canterbury, Ashburton, and South Canterbury – a uniform bag limit of 8 has been agreed on for the high-country lakes, although varying limits (10, 12, 12) are in force in the remainder of the districts. If the data for the three districts are combined, the average abundance of fish in the high-country lakes is less than in the lowland waters, and, if a uniform reduction in catch is desired, there is therefore justification for a lower limit in these waters. The differences between the three districts are considerable, however, and uniformity between them tends to produce different results in each district. The average reduction produced by the limit of 8 in the combined high-country lakes is 1 per cent. To produce this effect in the six categories of waters would, on the data available, require approximate limits of

	High-country Lakes	Others
North Canterbury . . .	9	8
Ashburton	7	10
South Canterbury . . .	6	13

None of these limits differ by more than 2 from those actually in force. Only in the North Canterbury district is the principle of having a lower limit on the high-country waters incorrect if uniformity of catch reduction is regarded as the objective.

The effects so far discussed concern the average reduction in catch produced by the bag limit for complete acclimatisation districts or major parts of them. In any district there are many waters containing trout stocks of varying abundance. Where the same limit is applied to all these waters it may be expected to produce varying degrees of catch reduction. Table 47 shows the parameters of the bag distribution, and the reduction produced by the limit for a number of individual waters for which adequate amounts of data are available. For the waters marked with an asterisk the parameters are taken from Allen, 1955, Table 1, and were estimated by

the method of least squares. For the other waters they have been estimated graphically. In general there does not often appear to be very wide variation among the waters within one district, although in Otago, where the greatest number of waters have been examined, there is a considerable range, D varying from 0·7 to 14·5 per cent. In this district special mention may be made of the Shag River. Local regulations provide a special limit of 5 for this river, and the low value of n_{50} (0·54) shows that bag size on this river tends to be unusually low for Otago. The effect of the special limit is to produce a catch reduction (4·2 per cent) which is about the mean for the whole district, whereas if the usual district limit of 10 had been in force the catch reduction would have been only about 0·3 per cent.

The reduction in catch D is the direct effect of the bag limit. The fish saved because an angler has had to stop fishing on reaching the limit remain in the water and are still available to anglers. Some of them will be caught later so that the final reduction in catch (U) will be less than D. It has been shown (Allen, 1955) that $U = \frac{D\ (1-R_0)}{1-DR_0}$ where R_0 is the proportion of takable fish caught by anglers if no limit is in force. When, as is often the case, D and R_0 are both small, approximately $U = D(1-R_0)$.

In an earlier part of this paper it was shown that there is reason to believe that at present the value of R in New Zealand waters rarely if ever exceeds 0·3. Table 46 therefore shows in column 6 the corresponding value of U for $R_0 = 0{\cdot}3$. The final reduction in catch which a limit of 5 would produce will therefore lie between the values given in columns 5 and 6 of the table. The reductions given by present limits are generally lower, so that the approximate equation will apply, and the final reduction in total catch can be taken to be between 0·7 and 1·0 times the value of D.

Many anglers probably obtain some satisfaction from the achievement of a limit bag, and the frequency of occurrence of limit bags in the various districts and waters studied is therefore of some interest. The last columns of Tables 46 and 47 therefore show the approximate percentages P of limit bags which can be expected. The figures have been obtained graphically by the extension of the regression lines fitted to the transformed distribution in each case.

The tables show that in general the value of P for any water is very similar to that of D, and that in most districts a limit bag is rarely attained.

Hobbs (1948), in discussing the records of one angler who had habitually taken very large bags, suggested that the bag limit, when attainable with reasonable frequency, might have the effect of increasing the total catch because anglers who would otherwise stop fishing might continue if they felt that they had a chance of achieving their limit. In considering the overall result produced by a bag limit, it is desirable to examine the extent to which this effect occurs. When it occurs the number of bags slightly less than the limit will be reduced and the number of limits will be increased when compared with the numbers which would occur with an unmodified distribution. The effect is likely to be at its maximum under conditions such that the limit is reached fairly frequently. Table 48 compares the actual and expected numbers of bags of the limit and of one less than the limit for some waters and districts which gave adequate samples of data and a fairly high expectation of reaching the limit. The expected numbers have been computed by distributing the actual total number of bags of limit size and one less between the two categories in

Table 48. Comparison of the Actual and Expected Number of Bags of Limit Size and of One Less for a Number of Waters Where Limit Bags Occurred Relatively Frequently

District	Seasons or Water	Number of Days	Limit		Limit–1		χ^2
			Actual	Expected	Actual	Expected	
Otago ..	Pomahaka ..	326	24	20·9	3	6·1	2·0
	Waipahi ..	83	5	6·6	3	1·4	2·2
	All	2,155	121	121·4	39	38·6	..
Southland ..	Aparima ..	200	19	15·0	1	5·0	5·8**
	All	1,045	69	57·3	9	20·7	8·2**
Otago-Southland	Mataura ..	467	58	54·4	12	15·6	1·1
Nelson ..	1946–49 ..	1,711	157	163·0	130	124·0	0·5
	1949–52 ..	3,293	80	75·0	51	56·0	0·8

the expected proportion. The chi-square test shows that, except in the two Southland samples, the divergence from the expectation is well below the significant level. It appears, therefore, that in most cases there is little if any tendency for anglers to continue to fish in the hope of attaining a limit bag. It may, however, occur occasionally, as seems to have happened in some of the group of anglers providing records for the Aparima. If the Aparima data are taken out of those for Southland, the remainder, covering the other waters in the district, show less divergence from expectation, giving $\chi^2 = 4{\cdot}7$, which is significant at the 5 per cent level. The data for Southland and Otago apply only to the 1951–52 season since this was the only one in which a limit of 10 was in force. The earlier limits of 15 and 20 respectively did not give a sufficiently good chance of reaching the limit. The Nelson data have been divided into two periods in which different limits were in force.

The extent to which a bag limit causes a redistribution of the catch, and thus benefits the less successful anglers, has been analysed elsewhere. It was shown that any benefit occurred only when a number of conditions were fulfilled; the group benefited took a small proportion of the total catch; the total fishing effort was heavy, so that anglers took a large proportion of fish reaching takable size; and the bag limit had exactly the right value for the particular circumstances. Even under these conditions the benefit to the less successful anglers is small, increasing their catch by only a few per cent. The last two conditions would be rarely fulfilled in New Zealand, and it is evident that the bag limit causes no appreciable benefit through redistribution of the catch.

3. RESTRICTIONS ON METHOD

SUMMARY

The principal restrictions on method limit the lures and baits which may be used. Many combinations are found among local regulations, but increasing restrictiveness generally prohibits successively worm, natural insects other than flies, natural minnows, natural flies, and artificial minnows. There is a general tendency for restrictions to increase progressively from the south to the north of New Zealand. In the extreme south there are very few restrictions on method, but

in the North Island a large proportion of waters are reserved for fly fishing.

Methods are sometimes prohibited because they are believed to cause interference with other anglers or to be "unsporting" and these aspects are not suitable for analysis in the present study. Methods are also prohibited because they are believed to be too destructive, and some data on this point are available.

Study of the rates of catch obtained by various methods shows that none are consistently or markedly more successful than the others. There is therefore no justification for the prohibition of any particular method as too effective. Under different conditions of weather and water different methods are most effective and prohibition of any method whatever therefore tends to reduce the proportion of time in which angling can be carried out at maximum effectiveness, and so reduces the total catch.

Certain methods are also believed to cause destruction of young fish by causing fatal injuries to undersized fish caught accidentally. Multiple-hook tackles may cause damage in this way but there is no evidence on this point. Recent overseas work has shown that about one-third of the undersized fish caught on worm succumb to their injuries, while mortality among fish caught on fly is negligible. In New Zealand there is no significant consistent difference in the proportion of undersized fish caught by the various methods, and thus worm fishing causes considerably more destruction of undersized fish than does fly fishing. The effect on the number of takable fish ultimately caught is, however, negligible except perhaps on waters where worm fishing is the favourite method.

The principal restrictions on method in force in New Zealand govern the baits and lures which may legally be used. The general regulations in force throughout the country limit these to "artificial or natural fly, insect, worm, crustacea, minnow, or fish." Local regulations may limit the use of any or all of these baits or lures on any particular water. There is a very wide variation among local regulations and so many different combinations of permitted lures are found that it is not practicable to divide waters into a small number of categories. In general, increasing restrictiveness of regulations prohibits successively worm, natural insects other than flies, natural minnows, natural flies, and artificial minnows. At one extreme all lures other than those prohibited by the general regulations are permitted. At the other extreme anglers are restricted entirely to the artificial fly. There is a well-marked difference between the northern and southern parts of the country, and particularly between the North and South Islands in the restrictiveness of regulations. In the South Island the majority of waters are open to all methods and very few are limited to fly only; in the two large southern districts of Otago and Southland only two minor waters are subject to any restrictions whatever on method. In the North Island there are only a few waters in which there are no local restrictions and the waters of about half the island are subject to "fly only" regulations.

It is difficult to find any basis for such a wide diversity of restrictions. The intentions underlying restrictions on method are probably of two main kinds. One con-

cerns the convenience and tastes of anglers; it is often believed that some methods, e.g. spinning, disturb the water and diminish the chances of following anglers to a greater extent than others; there may also be a feeling in some cases that certain methods are less sporting and should be discouraged as far as possible. Restrictions for such purposes as these involve questions of behaviour and taste and their justification lies outside the scope of the present paper.

The other intention underlying restrictions on methods is the protection or conservation of fish stocks. The basis of their imposition for this purpose is the belief that some methods are unduly destructive. There seem to be two main suggestions as to ways in which certain methods could be particularly destructive. They could be excessively effective, leading to the capture of too many fish of takable size, or they could cause damage to any undersized fish caught so that many of them died after return to the water. The data obtained in the present work provide some information as to the difference between the various methods in these respects.

Table 49 shows for ten of the principal waters the rate of catch obtained by each of the main methods. "Fly" includes both dry and wet fly and also large feather lures since these are permissible in "fly only" waters; "minnow" includes artificial spinning baits of all kinds (including spoons) and small natural fish on spinning tackles; "worm" includes all methods of fishing with this bait. Rates of catch are given on both daily and hourly bases since it has been shown earlier that each has some advantages as a method of expressing catch per unit effort. Since there are sometimes considerable differences in the average length of fishing day for different methods, the relation between rates of catch for the three methods sometimes varies on any one water according to the time unit employed. Only the data for the 1950–51 and 1951–52 seasons were recorded in suitable form for use in this analysis.

The relative rates of catch obtained by the various methods vary erratically from water to water, and each method achieved the greatest rate on some waters and the least on others. The differences are generally not great, particularly on waters where adequate samples of data are available for all methods as on the Mataura and Pomahaka. In earlier discussion of the significance of variation from season to season in the recorded rate of catch it was shown that variations of up to one third could arise from sampling errors, changes in identity of diarists and other factors, without indicating any change in the state of the fish stock. The same considerations arise with regard to differences in the rates of catch recorded for different methods. There is therefore no evidence that there is any difference in the normal rates of catch obtained by different methods and thus no justification for prohibiting any of them as unduly efficient.

In all the waters included in the table all methods permitted by the general regulations are allowed, but there are obviously great differences between waters in the extent to which they are used. The Motueka and Waipahi are essentially fly waters and other methods are rarely used; in the Motueka the use of the worm was never recorded in the two seasons studied. The same applies to a lesser extent to the Pomahaka, Aparima, and Mataura. At the other extreme is the Taieri, where the worm was the commonest method recorded; in the Waiau and Clutha spinning (usually with natural bait) was the commonest method. These differences arise largely from differences in the nature of the various waters, but it is probable that local custom also has an influence. It seems unlikely, for instance, that if the

Table 49. The Rate of Catch in Fish Per Day and Per Hour Obtained by the Three Principal Methods in Some of the Principal Waters

District	Water	Fly				Minnow				Worm			
		Days	Hours	Fish/Day	Fish/Hour	Days	Hours	Fish/Day	Fish/Hour	Days	Hours	Fish/Day	Fish/Hour
Nelson ..	Motueka ..	396	1,012	**2·29**	**0·89**	90	208	1·78	0·77	..	..	..	..
Otago ..	Clutha	41	120	1·83	0·62	362	1,564	2·18	0·54	216	1,174	**3·54**	**0·65**
	Mahinerangi-Waipori	15	109	1·60	0·22	117	737	**2·88**	**0·46**	86	643	2·38	0·32
	Pomahaka ..	467	1,803	3·93	1·02	176	780	3·69	0·84	89	360	**4·27**	**1·05**
	Taieri	57	162	2·00	**0·70**	109	437	**2·22**	0·57	84	503	1·06	0·18
	Waipahi	185	809	4·03	0·93	7	44	6·29	1·00	18	80	**7·45**	**1·67**
Southland ..	Aparima	138	464	3·22	0·96	57	221	**4·94**	**1·28**	41	123	2·76	0·92
	Oreti	47	197	2·18	0·52	50	259	**3·78**	**0·87**	26	146	1·73	0·31
	Waiau	56	259	**2·77**	**0·60**	315	1,002	2·33	0·50	16	80	1·69	0·34
Otago-Southland	Mataura	471	2,313	4·67	0·95	284	1,568	4·03	0·72	119	483	**4·79**	**1·18**

Motueka were situated in Otago, minnow and worm would be used as little as is actually the case. Local conditions will have influence between different sections of major rivers, and there is no doubt that if the results were subdivided in this way different methods would sometimes be found to be used predominantly in different parts of the same river.

Regulations limiting the methods that may be used may reduce catches in a more indirect way. It is well known that different conditions of weather and water favour different fishing methods. Regulations which permit the use of a wide range of methods therefore allow fishing at maximum efficiency for a greater proportion of the season than do regulations which limit the range of methods. They therefore allow a greater total catch to be taken. Restrictions on methods will tend to reduce the catch whatever methods are prohibited, and there is no reason, on grounds of efficiency, for selecting any particular methods rather than others for this purpose.

The second way in which certain methods are sometimes considered to be unduly destructive of fish stocks is by damaging undersized fish so that they die after release. This suggestion is most commonly made with regard to two methods; these are spinning with tackle embodying numerous or multiple hooks, and worm fishing.

Tackles with numerous hook points may perhaps become attached to fish in such a complex way that it is impossible to detach them without doing more or less serious damage to the fish. In the absence of any critical experiments, it is not possible to determine the magnitude of this effect.

The worm and other soft natural baits are much more frequently taken well into the mouth or swallowed by the fish than are artificial lures. There is therefore a much greater risk of internal damage to the eyes, gills, throat, heart, etc., and this can have serious effects. Shetter and Allison (1955) compared the survival of brook, brown, and rainbow trout caught on fly and on worm on several streams in Michigan. Averaged over a number of experiments they found that 20 to 42 per cent, according to species, of fish caught on worm were dead by the following morning, while of fish caught on fly only 0 to 11 per cent died. Roughly, therefore, one-third of the fish caught on worm were killed, but a negligible number of those caught on fly.

In comparing the destruction of young fish in this way by various angling methods, it is necessary to consider for each method not only the proportion of undersized fish which die as a result of hooking, but also the proportion of undersized fish actually caught. Thus a method which killed many of the fish hooked would do little serious harm if it led to the capture of few undersized fish. The proportion of undersized fish in catches obtained by various methods has been discussed in an earlier section, and data for some of the principal waters are shown in Table 15. This showed that there was some variation from water to water; waters fished mainly with fly tended to show a progressive reduction in proportion of undersized fish from fly to minnow to worm. Where worm and minnow were the most usual methods, worm gave the highest proportion of undersized fish, and there was no significant difference between fly and minnow.

Only a few waters gave sufficient data for this comparison but the results indicate that the damaging effect of worm fishing is at least not offset by a tendency for the number of undersized fish caught by this method to be relatively small. It seems very probable that in some waters worm fishing may cause the deaths of considerably more undersized fish than does fly fishing. Minnow fishing cannot be brought into the comparison since not enough is known of the damage it causes.

The destruction of young fish by worm fishing could, however, only justify the prohibition of this method if it were on a large enough scale to cause an appreciable reduction in the stock of fish. Some indication of the extent to which this is likely to occur can be obtained from the data in Table 15. Of the waters included in this table, the Taieri shows the highest proportion of undersized among the fish caught with worm, and therefore provides an extreme example for discussion. The table records the capture by a particular group of anglers in two seasons of 394 takable and 162 undersized fish caught on worm. If it is assumed, on the basis of Shetter and Allison's results, that one-third of the small fish caught on worm die, this amounts to 54 fish. These fish are undersized and would be at least one year (more probably two years) younger than the average takable fish caught by anglers; at the most 40 per cent (22 fish) would have survived to reach the average size at which fish are caught. It has been shown earlier that in New Zealand the proportion of takable fish actually caught rarely exceeds 30 per cent. Thus the effect of the recorded worm fishing would be to reduce the catch of the same group of anglers in subsequent years by about 7 fish, or less than 2 per cent of their actual season's catch.

The figures used in this example are obviously very approximate throughout but in every case an extreme value which would tend to give the highest final result has been selected. It seems very unlikely, therefore, that prohibition of worm fishing would ever add more than a very small percentage to the stock and to the total catch of takable fish. The addition could only approach significant proportions where worm fishing was extensively used, so that its prohibition could adversely affect a large group of anglers for a very small gain. Where there is little popular interest in worm fishing the saving produced by its prohibition would be completely negligible.

VII REFERENCES

ALLEN, K. R.

1951 *The Horokiwi Stream, a study of a trout population.* Fish. Bull. Wellington, N.Z. 10.

1953 *A method for computing the optimum size-limit for a fishery.* Nature, 4370: 210.

1954 *Factors affecting the use of restrictive regulations in fisheries management. 1. Size limits.* N.Z. J. Sci. Tech. 35, B: 498–529.

1955 *Factors affecting the use of restrictive regulations in fisheries management. 2. Bag limits.* N.Z. J. Sci. Tech. 36, B: 305–34.

ANSCOMBE, F. J.

1948 *The transformation of Poisson, binomial and negative-binomial data.* Biometrika, 35: 246–54.

BLISS, C. I. and R. A. FISHER

1953 *Fitting the negative binomial distribution to biological data and note on the efficient fitting of the negative binomial.* Biometrics, 9 (2): 176–200.

CALHOUN, A. J.

1950 *California angling catch records from postal card surveys: 1936–48; with an evaluation of postal card non-response.* Cal. Fish & Game, 36 (3): 177–234.

CHAMBERLAIN, T. K.

1943 *Research in stream management in the Pisgah National Forest.* Trans. Amer. Fish. Soc. 72: 150–76.

COOPER, E. L.

1953 *Returns from plantings of legal-sized brook, brown and rainbow trout in the Pigeon River, Otsego County, Michigan.* Trans. Amer. Fish. Soc. 82: 265–80.

CUNNINGHAM, B. T., N. T. MOAR, A. W. TORRIE, and P. J. PARR

1953 *A survey of the western coastal dune lakes of the North Island, New Zealand.* Aust. J. m. & f.-w. Res., 4: 343–86.

HOBBS, D. F.

1948 *Trout fisheries in New Zealand; their development and management.* Fish. Bull. Wellington, N.Z. 9.

1953 *The Taupo fishery investigations.* N.Z. Marine Dept. Duplicated report.

HUNTER, J. S. and D. H. FRY.

1940 *Progress report on game kill statistics.* Cal. Fish & Game, 26 (4): 310–33.

KIDSON, E.

1950 *The elements of New Zealand's climate,* in *New Zealand Weather and Climate.* N.Z. Geog. Soc. Misc. Ser. 1: 1–39.

LORD, R. F.

1946 *The Vermont "test-water" study.* Vermont Fish and Game Serv., Fish. Res. Bull., 2.

MICHIGAN CONSERVATION DEPARTMENT

1928 Fourth Biennial Report, 1927–28.

MOTTLEY, C. McC.
1940 *The production of rainbow trout at Paul Lake, British Columbia.* Trans. Amer. Fish. Soc. 69: 187–91.

MULLAN, J. W.
1955 *An evaluation of Massachusetts' trout stream fishery.* Mass. Div. Fish & Game, Duplicated report.

NEEDHAM, P. R.
1938 *Trout streams: conditions that determine their productivity and suggestions for stream and lake management.* Comstock. New York, 1938. 233 pp.

N.Z. CENSUS AND STATISTICS DEPARTMENT
1953 *Population Census, 1951. II. Ages and Marital Status.*

N.Z. MARINE DEPARTMENT
1953 *Annual Report of the New Zealand Marine Department,* 1952–53.

PARROTT, A. W.
1934 *Some observations on the brown trout population of the Kakanui River (North Otago).* N.Z. Fishing and Shooting Gaz. 7. (5): 6–8.

PENNSYLVANIA FISH COMMISSION
1954 Pennsylvania Fish Commission. Combined biennial report for period ending May 31, 1954.

PERCIVAL, E.
1932 *The depreciation of trout-fishing in the Oreti (or New) River, Southland.* Fish. Bull. Wellington, N.Z. 5.

RICKER, W. E.
1949 *Mortality rates in some little-exploited populations of freshwater fish.* Trans. Amer. Fish. Soc. 77: 114–28.

RUPP, R. S.
1955 *Studies of the eastern brook trout population and fishery in Sunkhaze Stream, Maine.* J. Wildlife Management 19: 336–45.

SCHUCK, H. A.
1945 *Survival, population density, growth and movement of wild brown trout in Crystal Creek.* Trans. Amer. Fish. Soc. 73: 209–30.

SHETTER, D. S.
1944 *Anglers' catches from portions of certain Michigan trout streams in 1939 and 1940, with a discussion of indices to angling quality.* Pap. Mich. Acad. Sci. 29: 305–12.
1950 *The relationship between the legal-sized trout population and the catch by anglers in portions of two Michigan trout streams.* Pap. Mich. Acad. Sci. 34: 97–107.

SHETTER, D. S. and L. N. ALLISON
1955 *Comparison of mortality between fly-hooked and worm-hooked trout in Michigan Streams.* Mich. Dept. Cons. Misc. Pub. 9.

TAYLOR, N. H.
1948 Soil Map of New Zealand (S.B. 280); to accompany *A genetic classification of New Zealand soils*: N.Z. Soil Bureau Bull. 3. (In preparation).

THORPE, L. M., H. J. RAYNER, and D. A. WEBSTER
1947 *Population depletion in brook, brown and rainbow trout stocked in the Blackledge River, Connecticut, in 1942.* Trans. Amer. Fish. Soc. 74: 166–87.

VIII APPENDICES

APPENDIX 1. SUMMARY OF DATA FOR THE PRINCIPAL WATERS

The principal results derived from the diary data for each water for which sufficient records were available. The waters are arranged under acclimatisation districts. In the length and species columns the letters B, R, and Q, indicate brown and rainbow trout and quinnat salmon respectively. The small figures in the species column indicate: (1) contains quinnat salmon; (2) contains perch; (3) about 93% small quinnat salmon; (4) about 66% small quinnat salmon; (5) contains occasional quinnat salmon; (6) <1% small Atlantic salmon.

Water	Number of Days	Number of Hours	Number of Fish				Mean Length	Fish Per Hour	Fish Per Day	Per Cent Under-sized	Species	
			Under-sized	Takable Returned	Kept	Measured					*B*	*R*
ASHBURTON												
Ashburton	169	529	67	..	248	227	15·94B 29·62Q	0·47	1·46	21·3	100[1]	0
Rangitata	145	521	98	..	441	394	16·73B 26·0 Q	0·84	3·04	19·3	100[1]	0
Lake Heron	100	275	..	..	173	137	22·89B 16·11Q 17·00R	0·63	1·73	0	5[3]	2
AUCKLAND												
Arapuni Lake	107	396	51	..	294	215	17·60	0·74	2·75	14·7	2	98
Awakino	183	910	805	..	599	467	18·12	0·66	3·27	57·3	4	96
Karapiro Lake ..	150	641	25	5	229	182	20·20	0·36	1·53	9·6	2	98
Kauaeranga	40	236	63	3	89	89	15·79	0·38	2·22	40·6	0	100
Mangahoe	27	140	22	..	77	80	19·87	0·55	2·85	22·2	0	100
Mangaotaki	72	364	66	..	232	201	18·01	0·63	3·22	22·1	3	97
Mangatutu	49	241	79	..	82	82	16·66	0·34	1·68	49·0	27	73
Maratoto	24	129	101	3	50	49	14·90	0·41	2·08	65·7	0	100
Waihou	231	892	377	7	512	454	17·43	0·58	2·21	42·1	0	100
Waiomou	74	309	266	..	288	287	17·43	0·93	3·89	48·0	0	100
Waipa	153	609	219	1	374	334	16·14	0·61	2·45	36·8	45	55
Waitekauri	63	380	124	..	212	173	15·32	0·56	3·37	36·9	5	95
Waitawheta	99	465	56	1	158	150	16·12	0·34	1·60	26·1	0	100
EAST COAST												
Hangaroa	136	644	100	28	223	217	18·90	0·39	1·64	28·5	0	100

Water	Number of Days	Number of Hours	Number of Fish				Mean Length	Fish Per Hour	Fish Per Day	Per Cent Under-sized	Species	
			Under-sized	Takable Returned	Kept	Measured					*B*	*R*
HAWKE'S BAY												
Black Creek	94	192	11	3	60	59	16·68	0·33	0·64	14·9	..	..
Manawatu	102	430	20	4	122	120	14·89	0·29	1·20	13·7	100	0
Marakeke	121	233	17	9	74	75	16·69	0·36	0·61	17·0	..	..
Tukipo	129	263	21	3	122	122	18·03	0·47	0·94	14·4	..	..
Tutituki	1,060	3,277	909	140	1,317	1,052	15·90	0·44	1·24	38·5	9	91
Waipawa	108	294	72	12	89	80	16·10	0·34	0·82	41·6	..	..
MARLBOROUGH												
Wairau	178	571	15	39	249	250	19·12	0·51	1·40	4·9	100	0
NELSON												
Baton	38	112	62	2	59	60	15·23	0·54	1·55	50·4	100	0
Buller	707	2,275	172	47	1,214	1,189	19·41	0·56	1·72	12·0	100	0
Gowan	62	207	13	..	122	97	19·96	0·59	1·96	9·6	100	0
Maitai	398	916	831	28	728	723	13·46	0·82	1·83	52·4	100	0
Mangles	49	161	2	1	89	81	21·48	0·56	1·82	2·2	100	0
Motueka	1,907	5,571	946	140	4,229	4,195	17·14	0·78	2·22	17·8	100	0
Owen	55	213	16	7	86	94	21·52	0·44	1·56	14·7	100	0
Riwaka	329	1,043	266	53	691	697	15·86	0·71	2·10	26·3	100	0
Lake Rotoiti	136	284	60	9	263	279	18·13	0·96	1·93	18·1	100	0
Takaka	173	313	8	4	87	69	21·25	0·29	0·50	8·1	100	0
Travers	105	401	4	5	231	225	20·99	0·59	2·20	1·5	100	0
Waimea	127	266	35	1	92	88	17·49	0·35	0·72	27·3	100	0
Wairoa	186	466	63	6	239	191	16·70	0·53	1·28	20·4	100	0
Wakapuaka	74	180	85	4	111	105	13·65	0·64	1·49	42·5	100	0
Wangapeka	252	940	79	16	467	460	19·58	0·52	1·85	14·1	100	0
Whangamoa	48	131	64	3	76	76	14·51	0·61	1·57	44·7	100	0
NORTH CANTERBURY												
Ashley	103	329	59	2	153	120	15·70	0·47	1·48	27·6	99[1]	1
Avon	140	543	55	19	283	140	13·82	0·56	2·02	15·4	99	1
Cam	71	177	28	2	82	65	16·35	0·47	1·15	25·0	100	0
Lake Coleridge ..	131	701	48	7	285	221	21·27	0·42	2·18	14·1	0[1]	34
Lake Ellesmere ..	292	1,130	13	9	560	469	18·18	0·50	1·92	2·2	100	0
Hororata	79	193	96	17	113	76	14·32	0·67	1·43	42·5	100	0
Lake Lyndon	91	262	90	0	116	91	15·13	0·44	1·27	43·7	0	100

Lake Shepherd ..	53	264	1	20	68	58	19·97	0·33	1·27	1·1	100	0
Selwyn	392	1,387	89	11	667	235	18·29	0·49	1·70	11·6	100	0
Styx	37	120	66	..	51	51	13·06	0·42	1·38	56·4	100	0
Waimakariri	347	1,292	276	35	445	341	29·18Q 16·01B 15·29R	0·37	1·28	36·6	87[1]	13

OTAGO

Butchers Dam	54	199	57	..	153	68	12·90	0·76	2·81	27·1	100	0
Catlins	238	790	199	..	643	512	18·00	0·81	2·70	23·6	100	0
Clutha	1,260	5,892	929	9	3,760	3,241	15·95	0·64	2·99	19·8	100[5]	0
Fraser's Dam	23	100	50	..	92	56	15·25	0·92	4·00	35·2	100	0
Kaihika	57	124	186	..	234	242	11·72	1·89	4·11	44·3	100	0
Leith	383	1,031	1,170	..	1,080	1,020	10·10	1·05	2·82	52·0	100	0
Mahinerangi-Waipori ..	465	3,106	145	3	1,056	1,052	16·06	0·34	2·28	12·0	100	0
Manorburn Dam ..	45	236	114	..	337	240	13·72	1·43	7·48	25·3	100[2]	0
Manuherikia Dam ..	138	658	40	..	642	642	14·40	0·98	4·66	5·9	100	0
Manuherikia River ..	37	135	3	..	134	134	16·92	0·99	3·62	2·2	100	0
Mimihau	311	1,377	947	60	1,665	1,678	13·62	1·15	5·11	35·5	100	0
Owaka	74	207	141	..	225	216	14·65	1·09	3·34	38·5	100	0
Pomahaka	2,383	10,116	5,863	53	9,477	8,379	13·77	0·94	3·98	38·1	100	0
Poolburn Dam ..	25	159	15	..	73	70	18·49	0·46	2·92	17·0	100	0
Puerua	57	189	43	..	101	101	15·43	0·53	1·77	30·5	100	0
Shag	353	791	180	..	695	690	13·80	0·88	1·97	20·5	100	0
Taieri	916	5,280	1,488	1	2,099	1,678	13·84	0·35	2·29	41·5	100[2]	0
Taylor's Creek ..	89	246	25	..	437	436	12·66	1·77	4·91	5·4	100	0
Tokomairiro	101	565	33	..	302	277	15·00	0·53	2·99	9·8	100	0
Tomahawk Lagoon ..	135	608	18	..	141	125	14·83	0·23	1·04	11·3	100	0
Waikaia	261	902	388	..	770	759	13·87	0·85	2·95	33·4	100	0
Waikouaiti	117	397	43	..	163	161	15·61	0·41	1·39	20·8	100	0
Waipahi	898	4,245	2,013	4	3,563	3,455	13·61	0·84	3·97	36·0	100[2]	0
Waipori River	334	1,886	514	..	815	756	12·86	0·43	2·44	38·7	100	0
Waiwera	273	859	696	..	769	742	13·21	0·89	2·82	47·6	100	0
Wyndham	236	1,303	468	14	1,141	1,122	15·10	0·89	4·83	23·1	100	0

Water	Number of Days	Number of Hours	Number of Fish				Mean Length	Fish Per Hour	Fish Per Day	Per Cent Under-sized	Species	
			Under-sized	Takable Returned	Kept	Measured					*B*	*R*
SOUTH CANTERBURY												
Lake Alexandrina	238	1,112	7	12	387	384	21·22	0·36	1·63	1·7	8	92
Opawa	29	80	77	10	139	139	12·27	1·86	4·79	34·1	100	0
Opihi	498	1,604	396	100	1,144	985	14·58	0·78	2·29	24·2	100[1]	0
Pareora	154	521	117	67	484	444	14·36	1·06	3·15	17·5	100	0
Temuka	77	274	206	21	283	185	11·72	1·11	3·65	40·3	100	0
Tengawai	182	675	370	30	664	513	13·54	1·03	3·64	34·8	100	0
Waihi	94	262	335	30	325	283	11·51	1·35	3·44	48·5	100	0
SOUTHLAND												
Aparima	782	2,647	1,678	267	2,973	2,879	14·02	1·23	3·80	34·2	100[2]	0
Hedgehope	29	126	24	3	142	139	14·39	1·14	4·89	14·2	100	0
Lora	60	257	120	24	295	272	14·28	1·24	4·92	27·4	100[4]	0
Makarewa	125	460	65	52	402	386	15·16	0·99	3·19	12·5	100[2]	0
Mararoa	63	281	5	4	132	111	21·88	0·48	2·08	3·5	81	19
Morley	79	362	97	..	238	238	15·60	0·66	2·99	29·0	98	2
Orawia	162	618	172	16	725	723	15·30	1·20	4·48	18·8	99[2]	1
Oreti	487	2,203	869	218	1,457	1,444	15·21	0·76	2·99	34·1	100	0
Otamita	51	209	304	24	262	237	13·15	1·37	4·58	53·9	100	0
Otapiri	52	200	135	25	250	251	13·17	1·37	4·76	33·0	100	0
Waiau	1,014	3,438	369	56	2,393	2,332	17·47	0·71	2·36	13·1	79[6]	21
Waihopai	48	152	14	8	89	89	16·34	0·64	1·84	12·6	100	0
Waimatuku	54	238	13	2	163	163	15·89	0·69	3·02	7·3	100	0
Waimea	67	274	146	32	300	257	14·44	1·21	4·44	30·6	100	0
TARANAKI-HAWERA												
Kapuni	94	186	101	21	144	132	15·96	0·88	1·53	38·0	99	1
Kaupokonui	118	384	35	18	222	182	18·08	0·62	1·88	12·7	92	8
Ouri	25	108	25	3	96	57	15·12	0·92	3·84	20·1	100	0
Taungatara	37	207	51	4	110	106	17·93	0·56	2·98	30·8	100	0
Waiaua	29	144	103	4	88	88	18·37	0·64	2·99	52·8	100	0
Waiwakaiho	485	1,129	283	16	411	381	17·21	0·38	0·85	39·8	92	8

WAIMARINO												
Makara	..	119	191	16	..	140	138	15·96	0·49	1·17	10·3	100	0
Makatuku	..	103	205	188	10	155	139	11·12	0·69	1·51	54·8	96	4
Manganui-o-te-Ao	..	321	796	27	14	564	477	18·83	0·54	1·72	5·7	21	79
Mangawhero	..	607	1,225	218	87	758	734	14·63	0·61	1·25	21·6	98	2
Taonui	..	112	212	52	8	185	155	15·45	0·64	1·65	21·2	100	0
Whakapapa	..	166	259	36	..	211	198	17·83	0·69	1·51	16·4	34	66
WAITAKI												
Kakanui	..	54	304	143	..	146	146	14·25	0·48	2·97	49·4	100	0
WELLINGTON												
Hautapu	..	145	326	82	15	263	244	16·84	0·85	1·81	22·8	100	0
Hutt	..	92	200	56	9	105	92	15·43	0·57	1·14	33·0	100	0
Makakahi	..	156	453	79	5	419	368	14·49	0·94	2·68	15·7	100	0
Makuri	..	57	191	69	7	190	80	14·52	1·03	3·64	26·0	100	0
Manawatu	..	244	1,026	124	2	463	389	15·70	0·45	1·90	21·1	100	0
Mangatainoka	..	382	1,474	145	6	834	697	16·27	0·57	2·19	14·7	99	1
Otaki	..	113	261	29	5	151	98	19·02	0·60	1·34	15·7	100	0
Rangitikei	..	198	882	85	14	405	411	16·36	0·47	2·04	16·9	19	81
Ruamahanga	..	178	625	97	1	319	235	15·34	0·51	1·79	23·2	100	0
Waipoua	..	85	141	217	8	132	99	13·69	0·99	1·55	60·8	100	0
WEST COAST												
Arnold	..	143	492	44	31	254	250	16·30	0·58	1·77	13·4	100	0
Buller	..	54	139	1	..	76	77	17·04	0·55	1·41	1·3	100	0
Crooked	..	25	101	1	5	79	77	17·30	0·82	3·16	1·2	100	0
Grey	..	261	713	87	19	345	332	17·23	0·51	1·32	19·3	100	0
Ohikanui	..	27	119	1	..	59	60	22·23	0·50	2·19	1·7	100	0
WESTLAND												
Hokitika	..	44	120	6	..	65	57	17·28	0·54	1·48	8·5	100	0
OTAGO-SOUTHLAND												
Mataura	..	3,205	13,255	3,604	325	12,606	11,663	15·83	0·97	4·03	23·5	100	0
ASHBURTON - NORTH CANTERBURY												
Rakaia	..	120	494	14	..	182	122	19·88	0·37	1·52	7·1	97[1]	3
AUCKLAND-WAIMARINO												
Wanganui	..	1,004	1,826	751	22	1,575	1,394	15·81	0·62	1·57	39·4	58	42

APPENDIX 2. STATISTICAL ANALYSES

(a) The Relation Between Percentage of Undersized Fish, Mean Length, and Size Limit

In order to study the way in which the percentage of undersized fish in the catches is related to the size limit and mean length, a multiple regression analysis has been performed. This yields the regression equation $P = 46{\cdot}13 - 4{\cdot}428X + 4{\cdot}576L$ where P is the percentage of undersized fish, X is the mean length of takable fish and L the size limit. The standard errors of the regression coefficients on X and L are 0·46 and 0·99 respectively. The values of the correlation coefficients between pairs of variables are given by

$$r_{XL} = 0{\cdot}367$$
$$r_{PX} = -0{\cdot}568$$
$$r_{LP} = 0{\cdot}079$$

The mean length shows highly significant correlations with both the proportion of undersized fish and the size limit, but the direct correlation between the two latter variables falls well short of even the 5 per cent level of significance for 129 degrees of freedom (0·17). The significant positive correlation between mean size and size limit (r_{XL}) may arise from two causes. In waters containing trout populations of similar size distribution, the mean length of the takable fish will tend to vary with the size limit since this determines the size range of the portion of the population which contributes to the mean. A positive correlation will also be produced by any tendency to adjust size limits according to the size of fish in the population. To test this the correlation coefficient has been calculated for the waters in Appendix 1 between the size limit and the approximate peak length for the size-distribution curve, the latter being estimated by eye to the nearest inch. The value of r obtained, 0·267, is significant at the 1 per cent level. To avoid an artificial correlation caused by the fact that the minimum size at which a peak can appear rises with the limit, all waters having peaks below 12 inches, or subject to limits greater than 12 inches, have been excluded. In all, 112 waters were included in the analysis. The method of selection will tend to cut out some genuine correlation, and thus the result is highly significant. Although size limits are in general almost uniform within each acclimatisation district, the district limits are evidently sufficiently adjusted to the usual size of fish caught to help to produce the direct correlation between mean length and size limit which is referred to above.

The strong negative correlation between mean length and percentage of undersized fish (r_{PX}) arises naturally from the effect of fixed bag limits on populations of different size ranges. If any given bag limit is imposed on a series of trout populations having a similar spread of size the proportion of fish falling below the limit will decrease as the mean of the spread moves upward, and will thus give rise to the negative correlation which is observed. The size limit will have the effect of causing the mean size to increase rather more slowly than the modal size, but this is unlikely to reduce the degree of correlation seriously.

The smallness of the positive correlation between the size limit and percentage undersized (r_{LP}) is more complex in its origin and less easy to understand. For a group of populations of the same mean length, increasing the size limit should increase the proportion of the population which is undersized and should give a strong positive correlation. That this occurs in practice is shown if the correlations between size limit and percentage undersized are worked out for groups of waters

having mean lengths falling in one-inch groups. The values of r from the four largest groups, 13·0–13·9, 14·0–14·9, 15·0–15·9, 16·0–16·9, are respectively 0·40, 0·58, 0·58, 0·20. Of these, the second is significant at the 5 per cent level, and the third at the 1 per cent level. If there were no correlation between size limit and mean length, the overall correlation between size limit and percentage undersized would be of the same order as that found within individual size groups. The data, however, show that the mean length tends to increase with the size limit and that the percentage undersized decreases with increased mean length; these effects, when combined, will produce a tendency for percentage undersized to be negatively related to size limit, thus offsetting the effect found within size groups. The very small positive value found for r_{LP} is the resultant of these two effects.

(b) The Relation Between Years of Diary Keeping and Number of Days Fished per Season

Analysis of variance for the data given in Tables 23 and 24 shows that in both the Nelson and Otago districts the significance of the differences in number of days fished between years of diary keeping is in excess of the 1 per cent level. Regression equations for number of days on number of seasons have been therefore calculated for these and a number of other districts as follows:

Otago	$D = 21{\cdot}17 + 1{\cdot}78\,S$
Nelson	$D = 14{\cdot}54 + 1{\cdot}90\,S$
Southland	$D = 18{\cdot}97 + 6{\cdot}16\,S$
Waimarino	$D = 17{\cdot}86 + 0{\cdot}70\,S$
Auckland	$D = 9{\cdot}66 + 5{\cdot}57\,S$
Wellington	$D = 10{\cdot}19 + 6{\cdot}47\,S$
South Canterbury	$D = 33{\cdot}86 - 4{\cdot}13\,S$

where D is the number of days and S is the number of seasons.

In five out of the seven districts, including those with the largest amounts of data, highly significant positive regression coefficients occur. In Waimarino the coefficient is positive but not significant, and in South Canterbury, where the least amount of information is available, it is negative and just significant at the 5 per cent level. The remaining districts fall into two groups; in Otago and Nelson the regression coefficient is slightly less than 2, and in Southland, Auckland, and Wellington, it is about 6. The differences within these groups are not significant, but when two districts belonging to different groups are compared the difference is highly significant. The results suggest that there is a tendency for the coefficient to be less in districts where the diary scheme was continued for a longer period. This is not unlikely, since when the scheme lasts for only a short period the records covering the full number of seasons available would include those from anglers who would have kept diaries for further seasons if the scheme had continued. These anglers would have tended to fish on more days per season than those who would in any case have stopped keeping records at the time when the scheme happened to finish. The average number of days fished by the anglers keeping diaries for the full number of seasons covered by the scheme would therefore tend to be greater than it would have been for the same number of seasons if the scheme had continued longer, and hence the regression coefficient would be increased.

APPENDIX 3. CHANGES IN SIZE AND RATE OF CATCH

(a) Summary of Data

The summarised records of rate of catch and average size of fish for each water for which comparison between two or more periods is possible are tabulated. In the "rate of catch" columns, the first shows the number of days or hours and the second the average catch per unit time; italic numerals indicate hours and catch per hour and numerals in ordinary type indicate days and catch per day. In the "average size" columns the first shows the number of fish recorded and the second the average size; italics indicate mean lengths in inches and ordinary numerals are mean weights in pounds. Figures in brackets after some of the lengths are estimated mean weights to enable comparison to be made with the earlier records. In the records for Lake Heron in the Ashburton district B indicates brown trout and Q "land-locked" quinnat salmon.

The sources from which the data were obtained are indicated as follows:

1. Hobbs (1948).
2. General diary scheme.
3. Local diary scheme.
4. Individual diary.
5. Trapped females in spawning run (Hobbs, 1948).
6. Competition records.
7. Percival (1932).
8. Marine Department scale collection.

District	Water	Period	Rate of Catch		Average Size		Source
Ashburton ..	Ashburton ..	1931–1933	..	..	231	*12·82*	8
		1948–1952	..	..	194	*15·94*	2
	L. Heron ..	1917–1918	..	..	16B	23·27	4
		1950–1952	..	..	9B	22·89	2
					124Q	16·11	2
	Rangitata ..	1880–1900	..	..	859	3·27	1
		1900–1920	..	..	671	3·43	1
		1920–1940	..	..	1,329	2·90	1
		1948–1952	..	..	393	*16·73* (2·03)	2
Auckland.. ..	Awakino ..	1932–1937	..	..	36	*15·83*	8
		1937–1939	*224*	*0·88*	163	*15·17*	3
		1948–1952	*910*	*0·66*	467	*18·12*	2
	Kauaeranga	1935–1939	*114*	*0·67*	133	*14·75*	1, 8
		1948–1952	*236*	*0·38*	89	*15·79*	2
	Mangaotaki	1936–1939	*57*	*0·94*	46	*16·70*	3
		1948–1952	*364*	*0·63*	201	*18·01*	2
	Oraka ..	1928–1932	64	2·70	173	0·92	4
		1931–1939	..	..	60	*14·30* (1·27)	8
		1948–1952	27	2·36	58	*16·50* (1·95)	2
	Waihou ..	1928–1932	88	3·80	334	0·87	4
		1930–1939	..	..	133	*14·99* (1·46)	8
		1936–1939	*408*	*0·61*	248	*14·41* (1·30)	3
		1948–1952	231	2·21	454	*17·43* (2·30)	2
			892	*0·58*			
	Waipa ..	1931–1940	..	..	56	*15·70*	8
		1948–1952	..	..	334	*16·14*	2
	Waitawheta	1936–1939	*195*	*0·34*	67	*16·30*	3
		1948–1952	*465*	*0·34*	150	*16·12*	2
East Coast ..	Hangaroa ..	1925–1933	17	1·18	20	2·88	4
		1933–1939	23	0·57	13	2·40	4
		1939–1947	39	0·85	33	2·95	4
		1947–1951	136	1·64	217	*18·90* (2·93)	2
Hawke's Bay ..	Tukituki ..	1921–1931	*1,212*	*0·62*	757	1·02	7
		1947–1952	*3,277*	*0·44*	1,052	*15·90* (1·74)	2
Nelson	L. Rotoiti ..	1933	..	..	42	*17·50*	8
		1946–1952	..	..	279	*18·13*	2

District	Water	Period	Rate of Catch		Average Size		Source
North Canterbury ..	Cam ..	1917–1919	..	..	22	*14·70*	4
		1928–1936	..	..	66	*14·05*	8
		1948–1952	..	..	65	*16·35*	2
	Hororata ..	1920–1931	61	3·67	219	0·93	4
		1948–1952	79	1·43	76	*14·32* (1·27)	2
	Selwyn ..	1910–1920	..	..	452	*19·9*	5
		1920–1930	..	..	594	*18·9*	5
		1930–1940	..	..	2,162	*19·3*	5
		1940–1945	..	..	416	*19·1*	5
		1948–1952	..	..	235	*18·3*	2
	Waimakariri	1929–1937	..	..	157	*18·67*	8
		1947–1952	..	..	273	*16·01*	2
Otago	Catlins ..	1934–1939	..	..	60	*14·45*	8
		1946–1952	..	..	512	*18·00*	2
	Mahinerangi-Waipori	1932–1939	..	..	210	*16·64*	8
		1946–1952	..	..	1,050	*16·06*	2
	Mimihau ..	1910–1920	..	..	314	0·86	1
		1920–1940	..	..	415	1·04	1
		1940–1945	..	..	213	1·09	1
		1946–1952	..	..	1,678	*13·62* (1·10)	2
	Pomahaka ..	1882–1883	26	5·2	135	1·75	1
		1930–1940	..	..	294	1·38	1
		1935–1945	131	4·0	..	..	1
		1946–1952	2,383	4·0	8,379	*13·77* (1·13)	2
	Poolburn D.	1936–1938	..	..	531	*17·10*	8
		1946–1951	..	..	70	*18·49*	2
	Shag ..	1880–1900	..	..	846	1·16	1
		1900–1920	..	..	272	0·82	1
		1920–1940	..	..	550	0·70	1
		1940–1945	..	..	288	1·36	1
		1946–1952	..	..	690	*13·80* (1·14)	2
	Waikouaiti ..	1932–1936	..	..	132	*16·47*	8
		1946–1952	..	..	161	*15·61*	2
	Waipahi ..	1882–1883	46	1·7	..	..	1
		1880–1890	..	..	720	1·60	1
		1900–1920	..	..	698	1·07	1
		1920–1940	..	..	576	1·04	1
		1935–1945	51	2·9	..	..	1
		1946–1952	898	4·0	3,455	*13·61* (1·09)	2
	Waiwera ..	1879–1883	13	2·1	33	2·01	1
		1935–1945	24	2·2	143	1·24	1
		1946–1952	273	2·8	742	*13·21* (1·00)	2
	Wyndham ..	1910–1920	..	..	163	1·06	1
		1930–1940	..	..	140	1·09	1
		1940–1945	..	..	376	1·64	1
		1946–1952	..	..	1,122	*15·10* (1·49)	2
South Canterbury ..	L. Alexandrina	1917–1921	..	..	16	*26·30*	4
		1930–1939	..	..	52	*22·88*	8
		1947–1952	..	..	384	*21·22*	2
	Opihi ..	1880–1900	..	..	1,912	0·88	1
		1900–1920	..	..	3,758	0·87	1
		1930–1940	..	..	345	0·68	1
		1947–1952	..	..	985	*14·58* (1·34)	2
	Temuka ..	1880–1900	..	..	1,050	0·90	1
		1900–1920	..	..	589	0·71	1
		1920–1940	..	..	136	0·83	1
		1947–1952	..	..	185	*11·72* (0·70)	2
Southland ..	Aparima ..	1890–1910	..	..	136	0·83	1
		1911–1922	..	..	1,356	0·78	6
		1920–1940	..	..	229	0·86	1
		1947–1952	..	..	2,879	*14·02* (1·19)	2
	Makarewa ..	1930–1936	..	..	40	*15·75*	8
		1947–1952	..	..	386	*15·16*	2

District	Water	Period	Rate of Catch		Average Size		Source
Southland—*ctd.*	Oreti ..	1880–1900	..	..	3,165	0·94	1
		1900–1920	..	..	13,686	0·82	1
		1909–1923	..	..	322	0·76	6
		1920–1930	..	..	4,476	0·62	1
		1947–1952	..	..	1,823	*13·58* (1·09)	2
	Otapiri ..	1880–1900	..	..	233	1·02	1
		1890–1902	18	12·9	..	..	1
		1900–1920	..	..	48	1·08	1
		1930–1932	18	11·7	..	..	1
		1930–1940	..	..	210	1·07	1
		1947–1952	52	4·8	251	*13·17* (1·03)	2
Waimarino ..	Mangawhero	1931–1937	..	..	132	*14·39*	8
		1948–1952	..	..	734	*14·63*	2
Waitaki	Kakanui ..	1932–1934	231	3·81	901	*12·02*	3
		1934–1938	331	2·49	823	*13·00*	3
		1947–1952	54	2·97	146	*14·25*	2
Wellington ..	Makakahi ..	1890–1910	..	..	124	1·28	1
		1895–1905	*16*	*1·27*	..	..	1
		1940–1945	*234*	*1·22*	318	2·40	1
		1948–1952	*453*	*0·94*	368	*14·49* (1·32)	2
	Manawatu ..	1890–1900	*100*	*1·03*	..	..	1
		1890–1910	..	..	287	1·83	1
		1930–1945	..	..	224	2·02	1
		1940–1942	*131*	*0·86*	..	..	1
		1948–1952	*1,026*	*0·45*	389	*15·70* (1·68)	2
	Rangitikei ..	1929–1935	..	..	229	*15·43*	8
		1948–1952	..	..	411	*16·36*	2
West Coast ..	Crooked ..	1934–1936	..	..	45	*16·29*	8
		1949–1952	..	..	77	*17·30*	2
	Grey ..	1931–1934	..	..	52	*20·83*	8
		1949–1952	..	..	332	*17·23*	2
Southland-Otago ..	Mataura ..	1931–1936	..	..	101	*16·31*	8
		1946–1952	..	..	11,663	*15·83*	2
Auckland-Waimarino	Wanganui ..	1930–1937	..	..	166	*15·75*	8
		1946–1952	..	..	1,394	*15·81*	2

(b) Discussion by Districts

The districts are arranged in geographical order from north to south.

Auckland

The data for the period 1936–39 were obtained from a diary scheme run by the Auckland Acclimatisation Society. The data for 1928–32 were drawn from a diary kept by one individual angler. The most usual changes in this district in the period covered (16–24 years) are a decrease in the rate of catch and an increase in average size. In the Waihou there has apparently been a progressive increase in the size of fish caught, but the significance of this must be regarded as uncertain in the absence of detailed data as to the places fished. On this river there is a considerable difference in the nature of the fish population of the upper and lower reaches. Above the falls at Okoroire there is a very abundant stock of small fish, many of them less than the legal limit of 12 inches in length; below the falls the fish are much less numerous but of much greater average size.

East Coast

The data, derived prior to 1947 from a single diary, and afterwards from the general diary scheme, show that the fish population of the Hangaroa River has not undergone any significant change during the last 25 years. These conclusions are

supported by less complete results recorded in another diary covering the Hangaroa for much the same period.

Hawke's Bay

Percival (1932) has published information obtained from one angler's diary covering fishing in the Tukituki and Waipawa rivers from 1921 to 1931. These results are compared in Appendix 2 with those obtained from the Tukituki River under the general diary scheme between 1947 and 1951. The figures obtained from the Waipawa, which is a tributary of the Tukituki, are very similar. The results show a definite increase in the average size of fish between the two periods, and it may be noted that Percival pointed out that a tendency for the average weight to increase appeared in the 10-year period which he studied. The catch per hour has decreased by nearly one-third between the two periods; the significance of this decrease is emphasised by the fact that in none of the five seasons of the later period did the rate of catch rise as high as the overall mean for the early period, while in only two of the ten seasons of the early period did the rate fall as low as the overall mean for 1947–52.

Waimarino

There are no indications of any change in the size of fish in the only river in this district for which data are available.

Wellington

The average size of fish in the Makakahi seems to have undergone changes of a rather unusual kind. Hobbs (1948) pointed out that the average weight was nearly twice as great in 1940–45 as it was about 1900. This increase does not appear to have been sustained, and by about 1950 the average weight had reverted to its original level.

I am indebted to Mr D. F. Hobbs for providing an amended figure for the mean weight in 1940–45; the amended figure is shown in Appendix 2 and is different from that given in Table IV of Hobbs (1948). In the Manawatu there are slight indications of changes similar to those in the Makakahi, but they are less definite. In both rivers there has been a progressive decline in the average rate of catch.

The records for the Rangitikei cover a shorter period but they do not show any definite change in size during this time although there is some indication of a slight increase.

Nelson

The data for Lake Rotoiti, the only water in this district for which comparison is possible, do not indicate any change in the size of fish in this lake in the last twenty years.

West Coast

The Grey River shows one of the largest decreases in mean length of any water examined in this study. On the other hand, the Crooked River, which is part of the same system, shows no definite change.

North Canterbury

In the Cam and the Hororata there seems to have been some increase in recent years in the average size of fish caught, and in the Hororata this has been associated

with a decrease in the rate of catch. In the Waimakariri, which is a much larger river, the average size of the recorded fish shows a decrease, although this might have been caused by a larger proportion of the first sample being taken near the mouth of the river, where the average size probably tends to be greater.

In the Selwyn the average size of the rod-caught fish of 1948–52, which would include some immature fish, is consistent with the very contant average size of the mature females from 1910 onwards, which is shown by Hobbs' data.

Ashburton

There seems to be some evidence of a progressive fall in average size in the Rangitata; in particular, the sample of fish recorded in the general diary scheme has a noticeably smaller mean weight than any of the earlier samples. On the other hand the two samples from another large river in the district, the Ashburton, show a decided increase in average size during the twenty-year interval.

In Lake Heron the two small samples of brown trout show no sign of alteration in size despite the change in nature of the fish population in the interval. During the earlier period the salmonid population consisted entirely of trout, with brown trout predominating. During the 1930's quinnat salmon reached the lake in the course of their normal spawning migration, and a non-migratory "land-locked" stock became quickly established. These fish now greatly predominate in anglers' catches and, as the appendix shows, their size is considerably less than that of the trout, which has not been affected by the establishment, in abundance, of a related species.

South Canterbury

Data covering the average size of fish over a long period are available for only two rivers and one lake in this district. For both the rivers records were published by Hobbs (1948) for the period 1880–1945 and showed no significant change. For the Temuka, the additional data provided by the general diary scheme show that the mean weight still remained unchanged in 1947–52. In the Opihi, on the other hand, the mean weight recorded for 1947–52 is considerably higher than in any earlier period. The fish recorded by Hobbs were all taken with artificial fly, whereas those recorded under the general diary scheme were taken by a variety of methods. More detailed examination of the data shows, however, that although fish caught on fly tend in the Opihi to be slightly smaller than those caught by other methods, the difference is not great. Also, over 70 per cent of the fish recorded under the general diary scheme were caught on fly. The average weight of fish caught on fly and recorded in the general diary scheme is about 1·2 lb., and it is thus evident that the increased mean weight recorded in 1947–52 is not the result of the variety of methods employed on this occasion, but apparently represents an actual change in the state of the trout population of this river as sampled by anglers.

In Lake Alexandrina there are signs of a small but progressive decrease in average size, but in view of the small size of the early samples no great certainty can be attached to this.

There are no early data which can be used to make comparison of the rate of catch at different periods in this district.

Waitaki

The data obtained from the Kakanui river by a local diary scheme between 1932 and 1938 are divided into two sections because the size limit was raised from 9

inches to 10 inches before the 1934–35 season. It was raised again to 11 inches between the last two periods. The progressive increases in the average size of fish may be partly due to these increases in the size limit, but this does not account fully for the change. If an 11-inch limit is applied to the fish recorded in the 1932–34 period by excluding those of 9 inches and 10 inches, the 658 fish which remain have an average length of 12·83 inches, which is still much less than the length of the 1947–52 sample.

The mean daily bag does not appear to have changed greatly during the period covered by the records. In the 1932–38 records, days when no fish were caught do not seem to have been recorded, and this would tend to make the estimated mean bags too high. The more complete records kept in 1947–52 included about 29 per cent of blank days, and this suggests that the earlier records might be about 40 per cent too high, so that the most recent daily bags are at least as good as those of the earlier period despite the higher size limit.

Otago

There is some variation in the changes in average size shown by the records from the various waters in this district. In one tributary of the Mataura, the Wyndham, the results of the diary scheme confirm the rising average size which was indicated by Hobbs' data; in the other, the Mimihau, the average size has been almost constant in recent years. In the waters of the other main system of the district, the Clutha, the opposite tendency appears. In both the Pomahaka and the Waiwera there is a decline in average size which is still continuing, although in the Waipahi the most recent data support Hobbs' statement that after an initial decline the size of the fish had become stable. Among the independent river systems, the Shag shows some indication of a more complex variation, size having at first declined to a minimum value in the 1920–40 period and then risen again to about the previous level. The Waikouaiti, on the other hand, shows no definite indications of any change in average size. The apparent change in the Catlins is probably due to the inclusion in the second sample of a number of fish caught in tidal waters, since there is in this river a large difference between the size of fish in tidal waters and that of fish from farther upstream. A sample of 190 fish, mostly from upstream, which were taken between 1946 and 1950, had a mean length of 15·20 inches, and this suggests that no significant change had occurred since the earlier period.

The data available regarding average daily bags provide no indication of any significant change in abundance of fish in any Otago waters. In the Pomahaka the average is rather higher in the first period than in the later ones, while in the Waipahi and Waiwera the figures show a progressive increase. The number of recorded days in the early periods and the number of anglers who provided them are in each case so small as to make it impossible to attach any significance to the apparent differences.

Southland

Data covering a long period are only available for three waters in this district. In two of these, the Aparima and Otapiri, the earlier information presented by Hobbs showed that a very constant average size prevailed from an early date. In the Otapiri the results for 1947–52 from the general diary scheme are very similar to those for earlier years. The additional data, derived from competition records from 1911 to 1922 that have now become available for the Aparima, are in close

agreement with the earlier diary records, while the average size for 1947–52 is considerably greater than in any earlier period. The recent difference is probably more than can be accounted for by the fact that the fish of this period were taken by a variety of methods while those recorded by Hobbs were taken with artificial fly only. The competition records for 1911–22 refer to fish taken by all legal methods.

For the Oreti, Hobbs (1948) has pointed out that there is evidence of "long-standing depreciation . . . extended into the 1920's." The additional competition data for 1909–23 fit in closely with this series. The 1947–52 records however appear to show a marked increase in average size. The early diary records all refer to the middle reaches of the river, and it has been shown in Table 13 that the average size of the fish is smaller in this part of the river than elsewhere. The figure given for 1947–52 is also restricted to this part of the river and is therefore comparable in this respect with the earlier data. This figure is based on fish caught by all methods, and not only on fly as were all the earlier records except the competition results for 1909–23. A check shows that, as in the Opihi, removal of the small proportion of fish caught by other methods reduced the mean length by only about 0·5 inches and the mean weight by about 0·1 lb. The data therefore indicate that there has been a substantial rise in the average size of fish caught in the middle reaches of the Oreti during the last twenty years.

Records covering a shorter period are available for one other river, the Makarewa, which is a tributary of the Oreti. These show no indication of any change in the average size of fish during the last twenty years.

A comparison of the average daily bag is made only for the Otapiri; this appears to show a remarkable decrease in 1947–52 over the earlier periods, although the samples are rather small in all cases. For the Oreti, Hobbs (1948) has summarised data obtained from a diary kept by the late N. R. MacKay, who fished this river from 1889 to 1930, and has shown that throughout this period his mean daily bag was usually about 13 fish. The mean bag recorded by anglers fishing this river in 1947–52 was 2·99 fish, but a comparison between, on one side, a single highly skilled and hard-working angler with a great fund of local experience and, on the other, a variety of anglers of varying degrees of skill and experience and sometimes fishing for quite short days, seems of doubtful validity.

Boundary Rivers

Neither the Mataura, between Otago and Southland, nor the Wanganui, between Auckland and Waimarino, show any indication of a change in the mean length of the fish.

APPENDIX 4. THE TOTAL AND RELATIVE FISHING EFFORT AND ANGLING CATCH IN THE VARIOUS DISTRICTS

District	(1) Days Per Season	(2) Hours Per Day	(3) Hours Per Season	(4) Men's Whole-season Licences 1951–52	(5) Total Hours Per Season (× 1,000)	(6) Area (Square Miles)	(7) Hours Per Square Mile	(8) Population, Males (18 and Over)	(9) Males 18 and Over Per Square Mile	(10) Per Cent Licence Holders	(11) Fish Per Hour	(12) Mean Weight (lb.)	(13) Mean Weight Per Hour (lb.)	(14) Fish Per Angler	(15) Total Fish (× 1,000)	(16) Total Weight (× 1,000 lb.)
Ashburton	13·3	3·42	45·4	735	33·4	2,470	13·5	6,720	2·72	10·9	0·55	2·18	1·20	25·0	18·4	40·0
Auckland	9·7†	4·19	40·6	1,716	69·7	9,940	7·0	185,226	18·63	0·9	0·61	2·21	1·35	24·8	42·5	93·9
East Coast	8·3	4·15	34·3	71	2·5	1,720	1·5	8,997	5·23	0·8	0·43	2·80	1·20	14·7	1·0	2·9
Hawera	17·1	2·98	51·1	222	11·3	1,080	10·5	8,727	8·08	2·5	0·67	2·22	1·49	34·2	7·6	16·9
Hawke's Bay ..	24·1	2·90	69·8	605	42·2	4,190	10·1	28,229	6·74	2·1	0·41	1·78	0·73	28·6	17·3	30·8
Marlborough ..	14·1	2·48	35·1	114	4·0	4,510	0·9	7,518	1·67	1·5	0·61	3·13	1·91	21·4	2·4	7·6
Nelson	14·5†	2·92	42·3	317	13·4	4,230	3·2	13,672	3·23	2·3	0·66	2·28	1·51	27·9	8·8	20·2
North Canterbury ..	12·3	3·69	45·5	2,184	99·5	7,420	13·4	71,382	9·62	3·1	0·49	2·18	1·03	22·3	48·7	106·1
Otago	21·2†	4·40	93·3	2,109	196·8	8,340	25·9	48,647	5·83	4·3	0·74	1·36	1·01	69·0	145·6	198·0
South Canterbury ..	15·9	3·51	56·0	1,280	71·7	2,880	24·9	12,952	4·50	9·9	0·85	1·54	1·31	47·6	60·9	93·8
Southland	19·0†	3·73	70·9	2,139	151·7	4,580	33·1	22,156	4·84	9·7	0·97	1·65	1·60	68·8	147·1	242·7
Taranaki	16·7	2·98	49·7	311	15·5	1,130	13·7	14,483	12·82	2·1	0·39	2·22	0·86	19·4	6·0	13·4
Waimarino ..	17·9†	2·35	42·1	221	9·3	1,540	6·0	3,965	2·57	5·6	0·70	1·85	1·30	29·5	6·5	12·0
Wellington	10·2†	3·11	31·7	1,536	48·7	6,780	7·2	115,531	17·04	1·3	0·65	1·75	1·14	20·6	31·6	55·4
West Coast ..	16·7	3·03	50·5	322	16·3	4,000	4·1	10,668	2·67	3·0	0·58	2·44	1·41	29·3	9·4	23·0
Westland	15·9	2·47	39·2	63	2·5	2,450	1·0	2,949	1·20	2·1	0·55	2·24	1·23	21·6	1·4	3·0
Bay of Islands ..	..	..	40·0	1	0·1	1,590	0·1	5,629	3·54	..	..	..	..	24·0	0·02	0·04
Hobson	..	..	..	..	..	1,210	..	2,839	2·35	..	..	..	..	..	..	..
Mangonui-Whangaroa	..	..	..	..	..	1,170	..	3,315	2·83	..	..	..	..	..	..	..
Stratford	..	..	40·0	121	4·8	810	5·9	2,828	3·49	4·3	..	..	..	24·0	2·9	6·4
Tauranga	..	..	40·0	114	4·6	650	7·1	7,936	12·21	1·4	..	..	..	24·0	2·7	6·0
Waiapu	..	..	40·0	13	0·5	1,370	0·4	2,481	1·81	0·5	..	..	..	24·0	0·3	0·7
Waimate	..	..	60·0	231	13·9	1,380	10·1	2,944	2·13	7·8	..	..	..	45·0	10·4	14·6
Waitaki	..	..	60·0	290	17·4	3,090	6·2	6,084	1·97	4·8	..	..	..	45·0	13·0	18·3
Wanganui	..	..	40·0	74	3·0	1,090	3·0	10,789	9·90	0·7	..	..	..	24·0	1·8	3·9
Whangarei	..	..	40·0	5	0·2	940	0·2	9,041	9·62	0·1	..	..	..	24·0	0·1	0·3
Rotorua	..	..	62·3	4,353*	271·2	7,800	34·8	10,649	1·37	40·9	0·56	3·53	1·98	34·9	151·9	536·1
Taupo	..	..	114·8	3,530*	405·2	1,190	340·5	908	0·76	388·8	0·51	4·60	2·35	58·5	206·7	950·7
Southern Lakes ..	..	..	32·6	1,224*	39·9	12,350	3·2	2,015	0·16	60·7	0·62	3·13	1·94	20·2	24·7	77·4

*Equivalent number of whole-season licences which would give the same effort if all fishing were done by whole-season licence holders as is assumed in other districts. †These figures are derived from the regression equations given on p. 145.

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